



# Exploring the Caged *Hen-Delta* Antenna for Amateur Radio

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v1.0w

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*This paper represents my 2-year exploration of the relatively unknown ‘skeleton slot’ Hen-Delta antenna. This is a versatile ‘little’ loop antenna with a tiny turning radius, surprising DX performance, and stunning broadband qualities when caged – definitely worthy of study by all amateurs, but especially those who live in noisy cities or suburbs*

*where permanent masts and towers are not permitted, or who simply prefer ‘stealthy’ – or low cost – DX antennas. I think you will find the caged Hen-Delta an intriguing design... and I hope you will share my enthusiasm for it!*

*– John AE0EN*

You may zoom in on most photos and illustrations to more clearly see details.

This 122 page, ~172MB document may be freely downloaded from Archive dot org at:  
<https://archive.org/details/caged-hen-delta-antenna>. Note this is the **only** official and updated download site.

Below the archive viewer there are download options – choose PDF, which provides an interactive Table of Contents. Parts, products, and sources that I have used are mentioned for the convenience of the reader. I have no affiliation with any of them.

## Acknowledgments

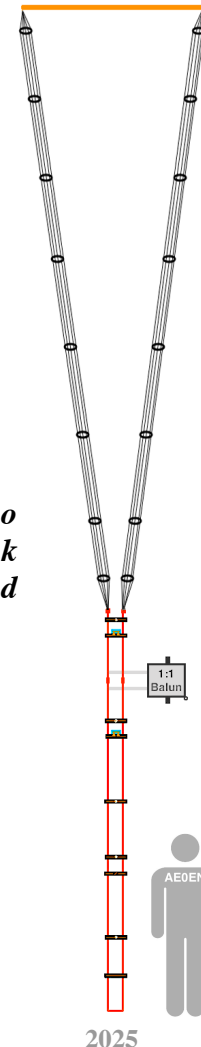
My grateful appreciation to my son **David Hackett, AE0IZ**, for his *many* technical analyses, insights, discussions, and invaluable assistance, without which this project would not have been possible.

My compliments to **John Portune W6NBC** and **Jim Bailey W6OEK** for creating the first Hen-Delta design in a 6m version.

My antennas are caged, scaled-up, sometimes multi-band variants of their original design. Here is a link to their article:

[6m Hen Delta by John Portune W6NBC and Jim Bailey W6OEK](#)

In remembrance of my friend and coworker, Don Wittlich, WN9V (SK) who first suggested I might enjoy amateur radio. I *have*, Don, thank you!



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# A Brief Overview of the Caged Hen-Delta Antenna

## Features:

- Bidirectional with nearly 1 S-unit of azimuth gain at a low elevation angle: “Performance similar to a 2-element yagi.”
- Very quiet (very good signal to noise ratio), important in a noisy city or suburban environment.
- Very broadband when caged.
- Very small turning radius (about 7% of a wavelength, compared to 25% for a horizontal dipole) and thus very space efficient.
- The tuning stub design makes it easy to tune and very tolerant of minor dimensional variations.
- Easily tuned with a graphing antenna analyzer (such as my RigExpert AA230-Zoom with its companion AntScope software).
- Tuning stub design allows multiple bands on the same antenna. [See Appendix-5 for a working 6-band, 6m-20m Hen-Delta.](#)
- A modest gain, *low cost* DX antenna when its top element is greater than one wavelength above ground. Mine are at 1.2 wavelengths.
- Horizontally polarized, which helps to suppress vertically polarized city noise.
- Easily constructed and fairly lightweight (can be made far more lightweight than those below). Reasonably stealthy when painted.
- Can be built to be somewhat collapsible and thus transportable.
- Requires a 1:1 current balun a short distance from the feedpoint.
- Tested to 700W-800W SSB on 10m-15m, should easily handle 1500W.

*‘Real world’ **SSB** performance with my 10m and 15m Hen-Deltas this year. I have worked dozens of very distant amateurs with just 100W, but a modest amp of 400W or more does help them hear you, especially during ‘pile-ups’ or marginal conditions...*

| Date       | Time  | RX Call | TX Fre... | RX Mode | RX Grid | RX Country         | Comment          |
|------------|-------|---------|-----------|---------|---------|--------------------|------------------|
| 2024-08-15 | 14:53 | 8177    | 21.270    | SSB     | PJ21ok  | Indonesia          |                  |
| 2024-08-11 | 01:12 | N5J     | 21.290    | SSB     | AI99xp  | Palmyra, Jarvis... | S. of Hawaii     |
| 2024-08-10 | 18:59 | S791    | 21.235    | SSB     | LI75rk  | Seychelles         | N. of Madagascar |
| 2024-08-06 | 18:03 | VY01    | 21.304    | SSB     | ER60tb  | Canada             | 10° from N. Pole |
| 2024-07-27 | 14:25 | NP21    | 21.260    | SSB     | EK77qs  | US Virgin Isla...  |                  |
| 2024-07-24 | 02:26 | VK20    | 21.260    | SSB     | QF54fp  | Australia          |                  |
| 2024-07-24 | 00:10 | EI30    | 21.290    | SSB     | IO63lr  | Ireland            |                  |
| 2024-07-19 | 00:55 | TI20    | 28.465    | SSB     | EJ79vw  | Costa Rica         |                  |
| 2024-07-10 | 01:08 | VE21    | 28.434    | SSB     | FN46pw  | Canada             |                  |
| 2024-07-10 | 00:43 | KL2V    | 21.288    | SSB     | BP51be  | Alaska             |                  |
| 2024-07-09 | 23:57 | VK91    | 28.460    | SSB     | RG30xx  | Norfolk Island     | E. of Australia  |
| 2024-06-28 | 00:36 | YB21    | 21.240    | SSB     | OI52jl  | Indonesia          | W. of Morocco    |
| 2024-06-27 | 23:54 | CT91    | 28.405    | SSB     | IM12ls  | Madeira Island     | NE Italy         |
| 2024-06-25 | 19:11 | T771    | 21.280    | SSB     | JN63fw  | San Marino         |                  |
| 2024-06-25 | 18:20 | S511    | 21.285    | SSB     | JN75dx  | Slovenia           |                  |
| 2024-06-24 | 23:22 | DO11    | 21.330    | SSB     | JO30rr  | Germany            |                  |
| 2024-06-24 | 23:00 | IK41    | 21.250    | SSB     | JN54dp  | Italy              |                  |
| 2024-06-24 | 22:51 | LY50    | 21.257    | SSB     | KO14wv  | Lithuania          |                  |

| Date       | Time  | RX Call | TX Fre... | RX Mode | RX Grid | RX Country    | Comment               |
|------------|-------|---------|-----------|---------|---------|---------------|-----------------------|
| 2024-06-04 | 15:20 | UY2V    | 21.238    | SSB     | KN48wi  | Ukraine       |                       |
| 2024-06-01 | 17:01 | OX3M    | 21.280    | SSB     | FQ56pm  | Greenland     |                       |
| 2024-06-01 | 15:33 | YB01    | 21.295    | SSB     | OI33js  | Indonesia     |                       |
| 2024-05-31 | 21:14 | PP21    | 21.230    | SSB     | FH99bd  | Brazil        |                       |
| 2024-05-30 | 00:35 | WP3E    | 21.320    | SSB     | EK68tb  | Puerto Rico   |                       |
| 2024-05-29 | 13:53 | EI9J    | 21.350    | SSB     | IO65ga  | Ireland       |                       |
| 2024-05-25 | 21:18 | CT1E    | 21.310    | SSB     | IM67aa  | Portugal      |                       |
| 2024-05-18 | 23:16 | VK21    | 28.465    | SSB     | QF56ss  | Australia     |                       |
| 2024-05-17 | 23:21 | C5C1    | 28.468    | SSB     |         | The Gambia    | Western Africa        |
| 2024-05-17 | 19:58 | CP71    | 28.485    | SSB     | FG78pl  | Bolivia       | Worked all S. America |
| 2024-05-17 | 19:04 | LX21    | 21.273    | SSB     | JN39bo  | Luxembourg    |                       |
| 2024-05-17 | 18:48 | SV2E    | 21.320    | SSB     | KN00um  | Greece        |                       |
| 2024-05-14 | 23:24 | HP11    | 21.230    | SSB     | FJ09fc  | Panama        |                       |
| 2024-05-14 | 22:11 | CE4J    | 21.280    | SSB     | FF45pt  | Chile         |                       |
| 2024-05-08 | 15:48 | YE9E    | 21.301    | SSB     | OI71qv  | Indonesia     |                       |
| 2024-05-08 | 14:40 | VY2E    | 21.295    | SSB     | FN76tr  | Canada        |                       |
| 2024-03-02 | 02:43 | FK81    | 21.300    | SSB     | RG37fr  | New Caledonia |                       |
| 2024-03-02 | 01:25 | BD11    | 21.223    | SSB     | OM89hu  | China         |                       |

↑  
700W (10m)  
800W (15m)  
} 100W

## A Brief Overview of the Caged Hen-Delta Antenna (continued)

### Hen-Delta Evolution and Anatomy

The Hen-Delta anatomy is shown in red in the illustration at right. There are just three main parts and two moving tuning pieces:

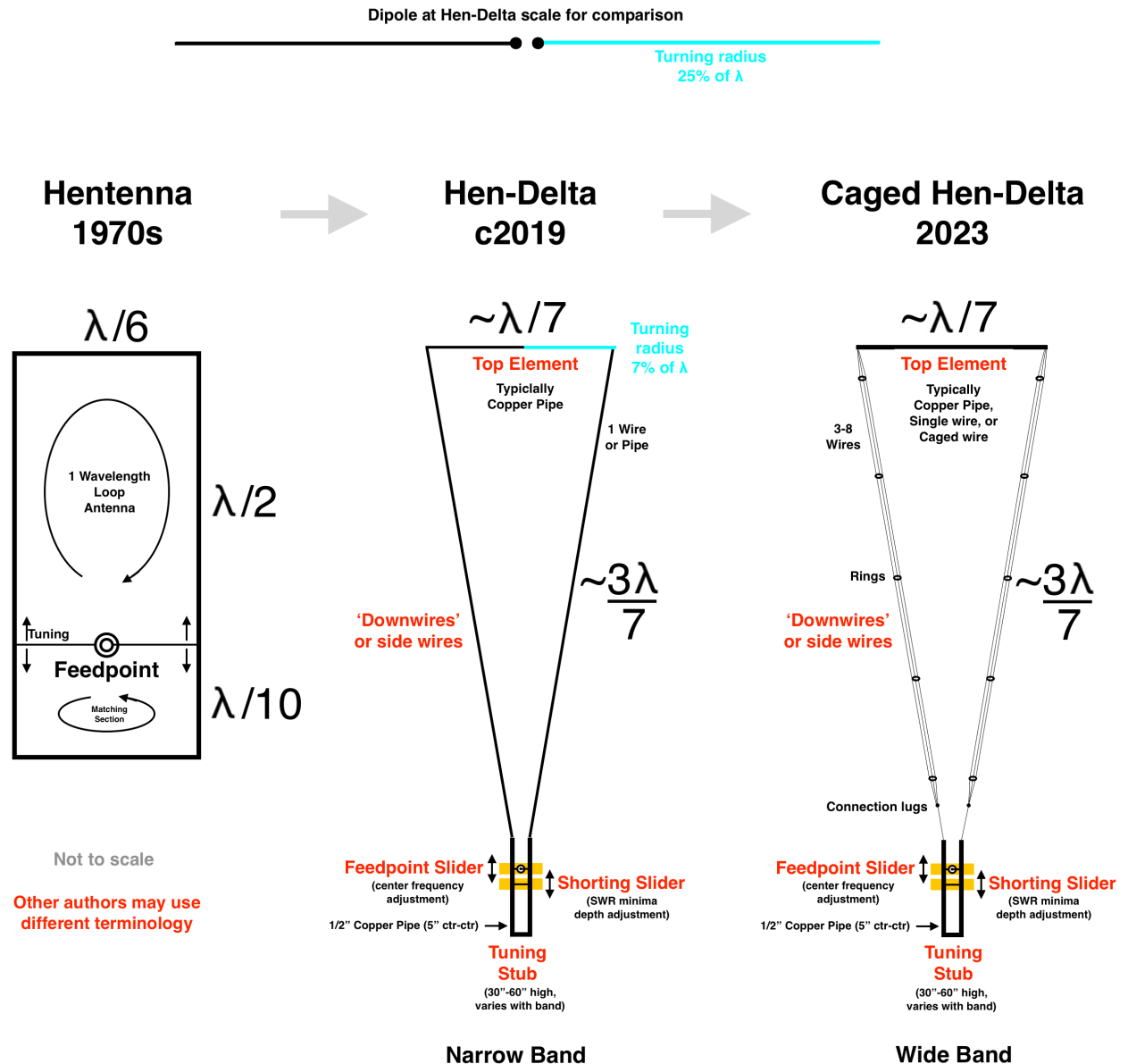
1. Top Element
2. 'Downwires' or side wires
3. Tuning Stub
  - A) Feedpoint Slider (1 per band)
  - B) Shorting Slider (1 per band)

*Other authors may use different terminology.*

The only difference between the original Hen-Delta and the new Hen-Delta (far right) is the 'caging' of the 'downwires'. Caging means that a set of parallel wires in a circular geometry acts as one conductor with an effective diameter much larger than that of a single wire. In Chapter 15 you will see that six wires in a 6" circle are equivalent to a conductor  $\sim 3.5"$  in diameter. It is this 'effective diameter' which determines the bandwidth of the any antenna.

The light blue lines and annotations show the small turning radius of a Hen-Delta relative to a dipole. The Hen-Delta has less than a *third* of the dipole's turning radius! Now that's *small*!

The small orange rectangles on the tuning stubs are hardwood 'sliders' roughly  $\frac{3}{4}" \times 1\frac{1}{2}" \times 9"$ , painted a flat color and spar varnished to seal the wood from the weather. Materials other than wood may be used. These serve as the mounting bases for the SO-239, the copper pipe clamps, connection wires, and a rain hood.



## A Brief Overview of the Caged Hen-Delta Antenna (continued)

### Examples of ‘as built’ Hen-Delta antennas:

Caging shown as built and tested, but not necessarily optimal.

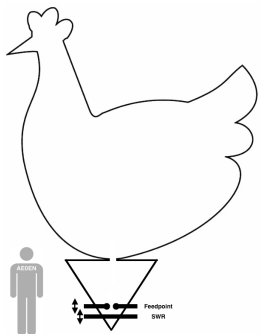
**History:** As best I can discover, the first rectangular ‘*skeleton slot*’ antenna was developed by B. Sykes, G2HCG in 1955 who patented the unique, high performance design, as describe in <https://worldradiohistory.com/UK/Short-Wave-UK/50s/SWM-1955-01.pdf> (p594). The popular rectangular Japanese *Hentenna* was designed in the 1970s by Tadashi Someya JE1DEU, Tadashi Okubo JH1FCZ, and JH1YST per <https://hamuniverse.com/hentenna.html> and <https://www.hamradio.in/projects/hentenna>, appearing in QST in 1982. ‘Hen’ is Japanese for ‘strangely interesting’ partly due to the fact that while primarily a vertical geometry, it functions with horizontal polarization.

The Hen-*Delta* is derived from the Hentenna, as modified by John Portune and Jim Bailey (see title page link), and retains the *skeleton slot qualities of the Hentenna* but with the elegant simplification provided by an easy to tune and versatile ‘tuning stub’ (see Appendix-5).

As discussed by [Paul Wade W1GHZ](#) in his *Chapter 7, Slot Antennas*, slot antennas (and thus skeleton slot antennas like the Hentenna and Hen-Delta) are *magnetic* rather than electric antennas – the E- and H-fields are swapped (Babinet’s Principle), thus a vertical Hen-Delta produces horizontal polarization. A skeleton slot antenna is created when the dimensions of the slot’s ground plane are reduced to nearly those of the slot itself – the qualities of the slot antenna are retained.

As Mark Haverstock, K8MSH, summarized in [On All Bands: Guide to Unusual Ham Radio Antennas](#) (used with permission):

*Skeleton slot antennas* are a version of the folded dipole. They can be easily rotated and are *bidirectional*. *Skeleton slots have high gain, a low angle of elevation, wide bandwidth, and performance similar to a two-element Yagi*. A vertical skeleton slot radiates like a horizontal dipole and has *horizontal polarization* – good for limited space.



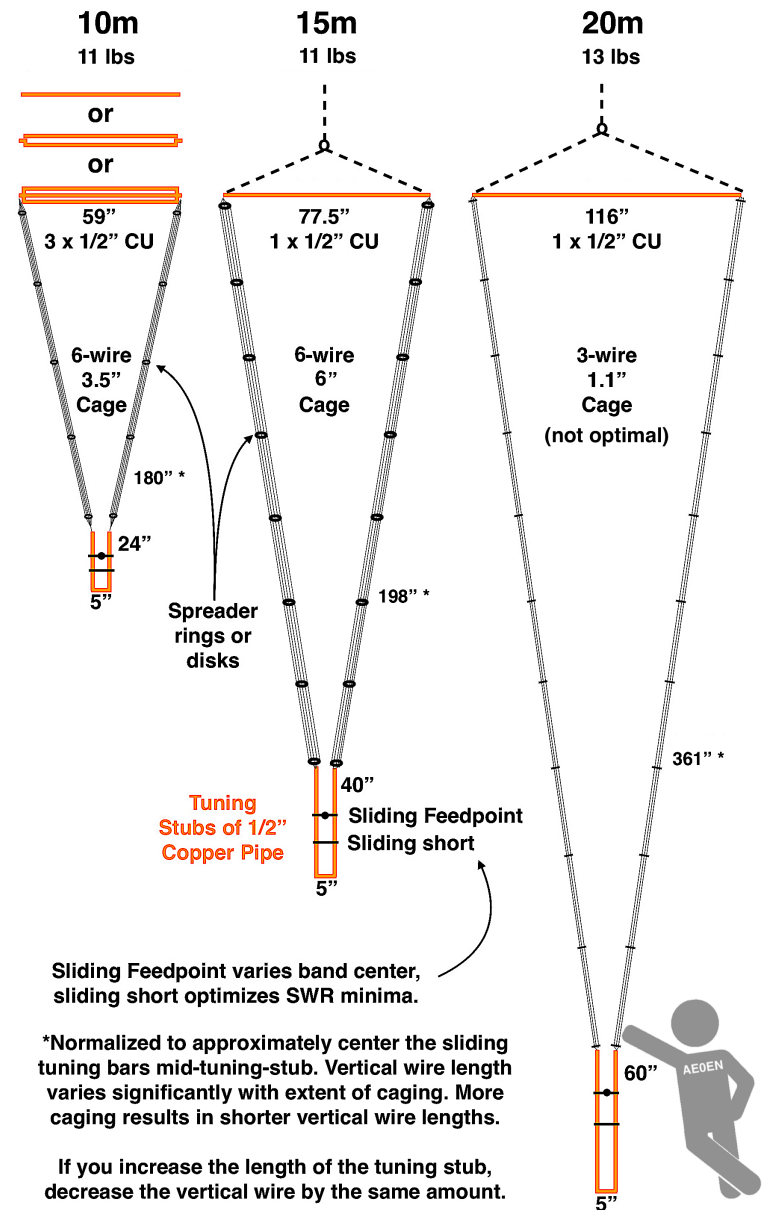
There are several variations including:

- Planar slot—microstrip and patch antennas
- Skeleton sleeve—ladder line antenna notched for multiple bands
- *Hentenna-like skeleton slot, with feedpoint off-center*

Left: **NOT** a Hen-Delta antenna!

Right: **Actual** Hen-Delta Antennas!

### 6m – 20m Hen-Delta Antennas (as built)



## A Brief Overview of the Caged Hen-Delta Antenna (continued)

In the early phase of this project I only had a single tree branch from which to suspend my Hen-Deltas and needed to swap antennas to change bands, so I suspended my Balun Designs Model 1115 1:1 Current Balun with a spar-varnished wooden 'hook' from the bottom of the tuning stub to allow it to be easily moved from one antenna to another. Later when I had two tree branch suspension pulleys operational, I used one current balun per antenna but kept the origi-

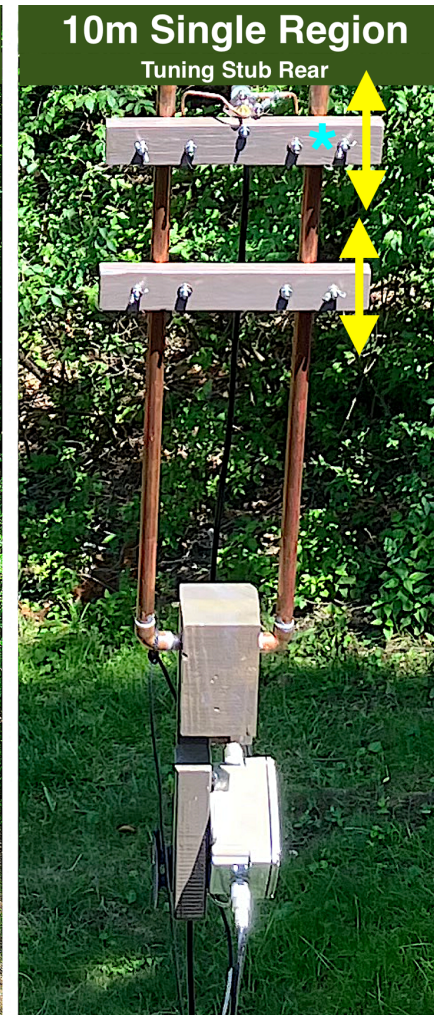
nal 'wooden hook' design for its versatility. These current baluns could alternatively just be attached to the bottom of the tuning stub via tie-wraps (zip-ties). Note that the weight of the tuning stub's copper pipe, sliders, the balun, and the wooden hook – several pounds – helps to keep the Hen-Delta's 'down wires' straight.

Note: Mid-2023 versions:

- 1) Center frequency adjustment (SSB)
- 2) Center frequency adjustment (CW)
- 3) SWR minima adjustment (SSB)
- 4) SWR minima adjustment (CW)

All PL-259 connectors are covered by rain hoods in future designs. At this early stage coax and baluns were brought indoors when not in use.

Early SO-239 mounts were horizontal. Later designs used a vertical SO-239 to eliminate coax bending stress.



Feedpoint Slider  
Center frequency adjustment

Shorting Slider  
SWR minima adjustment

\* Wingnuts were used in this early version, but 10-32 knurled brass nuts are a better choice.

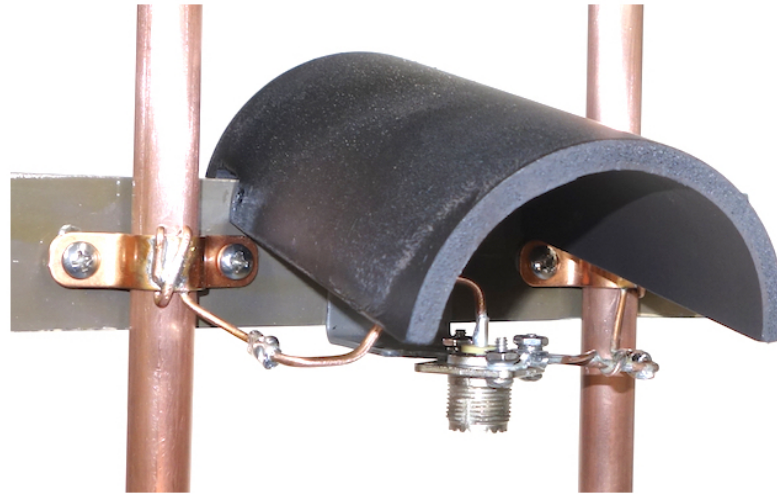
Wooden 'hook' (spar varnished)

1:1 current balun

Left: 10m SSB / 10m CW dual-tuning region experiment.

Right: Typical single band tuning stub.

## A Brief Overview of the Caged Hen-Delta Antenna (continued)



Rain hoods were later added just above the feedpoint and balun to keep the connections dry, but still accessible.



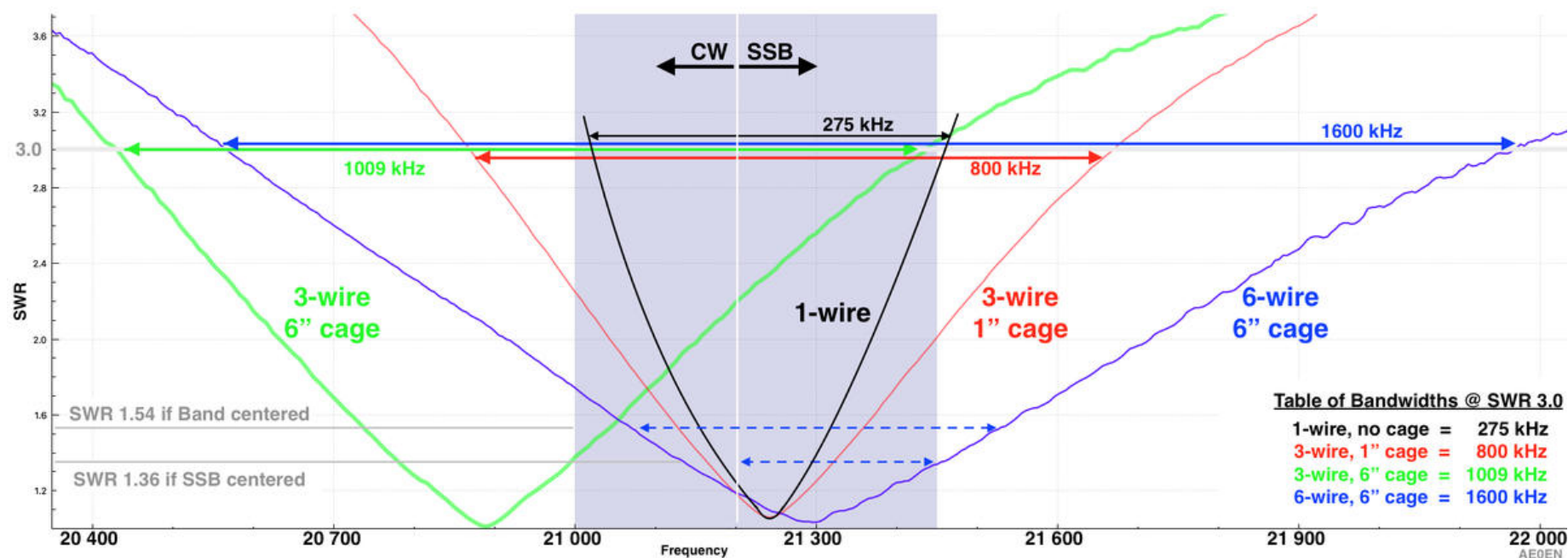
I had this made by one of those custom coffee mug companies.  
The other side has an outline map of the continents.

## A Brief Overview of the Caged Hen-Delta Antenna (continued)

With 1/2" copper pipe for the top antenna element and a *single* 12-gauge wire for the side wires, or 'down runs' (black trace, below), the Hen-Delta is far from offering broadband performance. **Caging remedies this easily and dramatically**, and applies to other antennas as well. Chapter 14 shows a similar effect for the 10m band. This was my first experience with caging any antenna.

The illustration below shows the dramatic impact of various degrees of caging. Note that the bandwidth of the 6-wire (purple trace) caged antenna is more than **five times wider** than the single-wire (black trace) uncaged antenna! (See inset table at lower right). Further details about caging will be found below.

Comparison of Bandwidths for 15m Hen-Delta Antenna  
of Various Cage Diameters and Wire Counts



**Definition:** The antenna's center frequency is the frequency where the SWR minima occurs. Sometimes this is referred to as the 'SWR *minima*'s frequency', or just 'minima frequency'.

# A Chronological and Evolutionary Exploration of the Caged Hen-Delta Antenna

## Introduction:

This paper is based up the episodic chronological postings on my QRZ page from 2023-2024. Although it has been significantly edited, the chapter organization retains some of the original flavor of the postings. Higher resolution illustrations have been utilized and in many cases new illustrations have been created (there are almost as many illustrations as pages) so that you may zoom in on most of them to see greater detail. **This is primarily a technical and reference paper, not a smoothly-flowing novel**, so please allow for a bit of redundancy and chronological ‘chunkiness’ in the chapter discussions. It was often much easier to update an old chapter with new data rather than move the entire chapter to maintain a rigid chronological order, so the chapter dates may occasionally seem jumbled.

My Hen-Delta experimentation began with my encountering the article [6m Hen Delta by John Portune W6NBC and Jim Bailey W6OEK](#) during a routine search for antennas. Their work transformed the 1970s Japanese rectangular ‘Hentenna’ into a more usable and elegantly tuned Hen-*Delta*.

While I had no interest in 6m, I knew that all antennas can be rescaled for different bands. I was enthusiastic for the design’s potential at my home. As far as I know I am the first amateur to build and study 10m, 15m, and 20m Hen-Delta variants, and I am very glad that I did so! I began with a 10m band antenna...

The first quality which caught my attention was that the Hen-Delta is narrow with a **tiny turning radius** (2.5’ for 10m) of only **~7% of a wavelength**. For me this meant that it could be hoisted high up into a suburban tree – masts and towers are not permitted here in suburbia – using a 1/4” Dacron (UV-resistant) rope and a 2” marine stainless steel sailing pulley (or ‘block’) painted dark brown to subdue the bright metallic parts. The small turning radius allows it to be rotated without hitting nearby tree branches – and *try that* with a 10m horizontal dipole with a turning radius 3½ times larger! The Hen-Delta can be steered using an endless variety of simple-to-clever home-built rotator mechanisms. Mine is among the simplest but works so well I have not felt the need to upgrade it.

My initial builds were quite basic and slowly grew in sophistication as I became increasingly familiar with the antenna design and my RigExpert antenna analyzer and software. I discovered – initially in small, tentative steps – that **caging** an antenna can result in spectacularly improved bandwidth – and a Hen-Delta is *easy* to cage. This was my first-ever experience with caging and I found cohesive information about the topic surprisingly difficult to find. It is *all* collected here!

Based on my experience, the most important aspect of caging is that – for **any** antenna – a cage diameter equal to 1% of wavelength produces about 80% of the maximum possible broadband improvement, and 2% of wavelength produces essentially 100%. For 10m band antennas, 1%-2% translates into cage diameters from 0.35 feet (0.1m) to 0.7 feet (0.2m), or about 4” to 8”. Caging is discussed in great detail below, and it is exciting to note that **an antenna need not be completely caged!** Even a partial, or ‘fractional’ cage can impressively broaden the SWR curve of an antenna – as the experiment in Chapter 16 below demonstrates. As it happens, the Hen-Delta is very easy to cage.

My initial test support wasn’t a tree limb at all, but a temporary (now removed) 2x2 test ‘crane’ mounted to my chimney’s 2x10 skirt, suspended over my wood deck and ~29’ above ground. It was very popular with local hawks... less so with local rodents and squirrels.

After the initial tests revealed the exciting DX performance of the 10m Hen-Delta, I ‘upped my game’ to a 43’ high tree limb – the one directly behind the hawk in the photo, as it happens. That meant that the top element would be at about 40’ or 1.2 wavelengths above ground – and, of course, the higher the better for *DXing* (see Chapter 24).

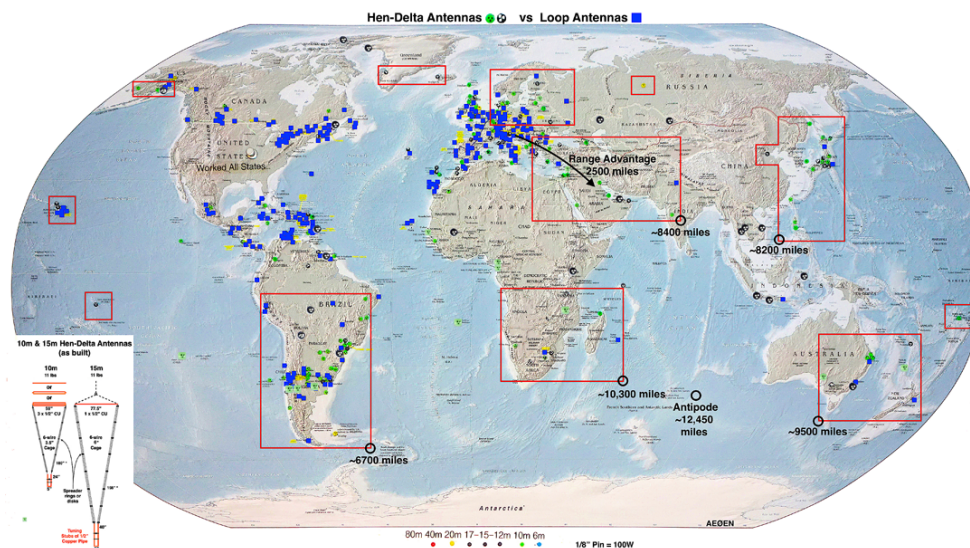


Impressed by the performance of the 10m Hen-Delta *relative to my other options*, I decided to build a 15m version, which also worked superbly. Swapping the two antennas to change bands was achievable but rather a nuisance, and a 15m antenna should really be higher above ground than 40' for best DXing... The next step was to build a second suspension location for the 15m Hen-Delta. After much arboreal study I found the perfect limb with forks (bifurcations) just above and below it to constrain the movement of the padded J-Hook which held the 2" marine-grade pulley and halyard line (see Chapter 25). It was about 58' above ground as measured with a laser distance meter, so the top element would be about 55' or 1.2 wavelengths above ground. Great! The only drawback was the need to use a slingshot to get a 'messenger line' through a target size of a 'salad plate', since I'm not very skillful with a slingshot! Well, I'm not going to describe the endless trial and error, hope and heartbreak of near-misses, in trying to get a 15lb monofilament fishing line through and over such a small target, with the weight spinning and arcing first one way and then another, and *then* halting its trajectory before it can hopelessly tangle in more distance foliage. It took hours and days to succeed. What I have learned about slingshots, messenger lines, and tree limbs over the years I have preserved for posterity in Chapter 25.

Naturally, a couple of inconvenient small branches had to be trimmed so the antenna could hang freely and rotate. That involved getting messenger lines over *those* branches to hoist a rope saw! Once I attached an angled 6' fiberglass

driveway marker pole to the top element itself in order to precisely drop a weighted line over a small, pesky branch. *Will this never end?* Yes! And it has a happy ending... but I will never forget the extent to which 'arboreous' means 'laborious'!

In five years I have worked ~~157~~ 174 countries so far (map below, somewhat out-of-date), **SSB-only**. The most recent 77 – and typically the farthest (see the red boxes on the map) – being almost exclusively with Hen-Delta antennas. Only the last 20 or so countries with more than 100W – typically 700W-800W. With a modest gain antenna like the Hen-Delta, an amplifier helps the distant station hear *you*. With good propagation you can often work anyone in **daylight** who is similarly equipped, just don't expect to out-shout '*the big guns*' during 'pile-ups' – those high gain yagis on tall towers running 1500W overwhelm me by 2-3 S-units, so your perfectly clear '59' signal is clobbered by dozens of thundering 59+20s. But be patient and you will get your turn... pass the time by thinking about how much less money you spent! Below is an edited 'pin map' illustrating the difference in range between my loop antennas (blue squares) and my Hen-Deltas (green and black pins with 3 dots on them). I haven't quite worked the antipode yet ('pode' rhymes with 'mode'), but I've come close! *If you are new to DXing*, try <https://www.dxmaps.com/spots/mapg.php> to see who is talking to whom on which bands and frequencies – use the cursor to hover over or click on a call sign to see their frequency, your best antenna angle, distance, etc.



**You may zoom in on this map.**

While it is difficult to compare antenna performance under non-laboratory conditions, let alone over several years of varying solar conditions, I would ‘guesstimate’ that the Hen-Delta antennas give me a range increase of about 2500 miles (4000 kilometers) compared to my various loops at similar heights. This is due to the Hen-Delta’s azimuth gain, quiet nature, and low take-off angle when greater than one wavelength above ground. [See Appendix 3 for a graphical comparison.](#) I rarely use my loop antennas much any more, except for bands not provided by my Hen-Delta antennas, like 40m and 17m.

In practical terms, for me this range increase is the difference between working one new country *every other month* during *excellent* propagation, and working one new country *per week* during ‘just’ *good* propagation.

Online articles discussing Hentenna and Skeleton Slot antennas – from which the Hen-delta is derived – have stated that the combination of modest gain *and* low elevation angle results in performance “similar to that of a 2- or 3-element yagi”, which is nearly 1 S-unit of gain. That also approaches the gain of a HexBeam but with a much smaller footprint. I suspect that the Hen-Delta is quieter than either, and – since a yagi typically has a narrow bandwidth – more broadband than either.

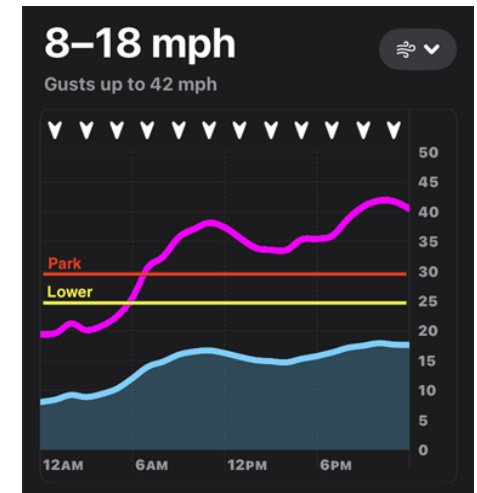
An interesting attribute of all bidirectional antennas is that they work both the *short path* and the *long path* simultaneously. In my experience – and with my working conditions – communicating long path is very rare and I don’t recall ever having done so. Interestingly, there is also such a thing as a ‘skew’ path, where the usual ‘great circle’ paths are not open, but easterly-westerly ‘off-path’ radio energy may refract *around* a MUF contour map ‘ridge’ or ‘island’ and then propagate more northwardly or southwardly than would typically be expected.

A minor disadvantage of bidirectionality is that signals from behind the antenna are not suppressed – the front-to-back ratio is 0 db (front = back). Signals from

the sides are mildly suppressed, and given the width of the azimuth beam it might be possible to slightly rotate the Hen-Delta to suppress unwanted noise, whether QRM (manmade) or QRN (nature made). I have not found bidirectionality to have ever been a disadvantage, and it does simplify rotator steering.

Of course, trees aren’t the most perfect antenna supports – just the best that *some of us* have access to – and I diligently *lower* my Hen-Deltas by 6’-8’ when wind gusts over 25mph are forecast or occur, to allow the limbs plenty of additional sway distance. When storm fronts or large thunderstorms are forecast or occur, I take the Hen-Deltas down entirely and ‘*park*’ them, draped over my deck railing. This reduces potential wind gust stress on the tree branches, the J-hooks, and the pulleys (see Chapter 25), as they represent significant investments in time and effort.

When practical, trees *do* represent a very *low cost* structural option compared to an expensive tower. Granted, mast and tower mounting would be superior – if allowed and affordable – and if you do or can have them then by all means design your own custom Hen-Delta mounting and rotator designs. Allow for the need to raise and lower the Hen-Delta quickly and easily for tuning, or for selecting a specific height in order to control the take-off angle for DX vs local ranges (see vertical mobility in Chapter 24). But for my home here in the suburbs, trees are the only way I can achieve these DX-enabling heights above ground... and with a degree of stealth.



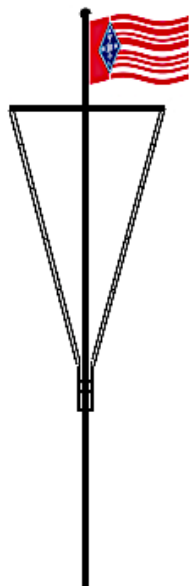
# (1) My Hen-Delta Learning Curve (in chronological order):

March-June 2023: My *first-ever* Hen-Delta, 10m at 29' above ground on my test crane. This Hen-Delta antenna lacked any caging – that was a later discovery.

*This is an unusual 'vertical' antenna in that it radiates horizontally polarized, predominately from the copper pipe at the top. Scaled up to 10m from the article [6m Hen Delta by John Portune W6NBC and Jim Bailey W6OEK](#). Also see (search on): "Antenna Fans: Try the Skeleton Slot" in 73 Magazine, May 1980, pages 80 and 81 or try this link:*

*[https://ia600900.us.archive.org/5/items/73-magazine-1980-05/05\\_May\\_1980.pdf](https://ia600900.us.archive.org/5/items/73-magazine-1980-05/05_May_1980.pdf) then scroll down to page 80-81.*

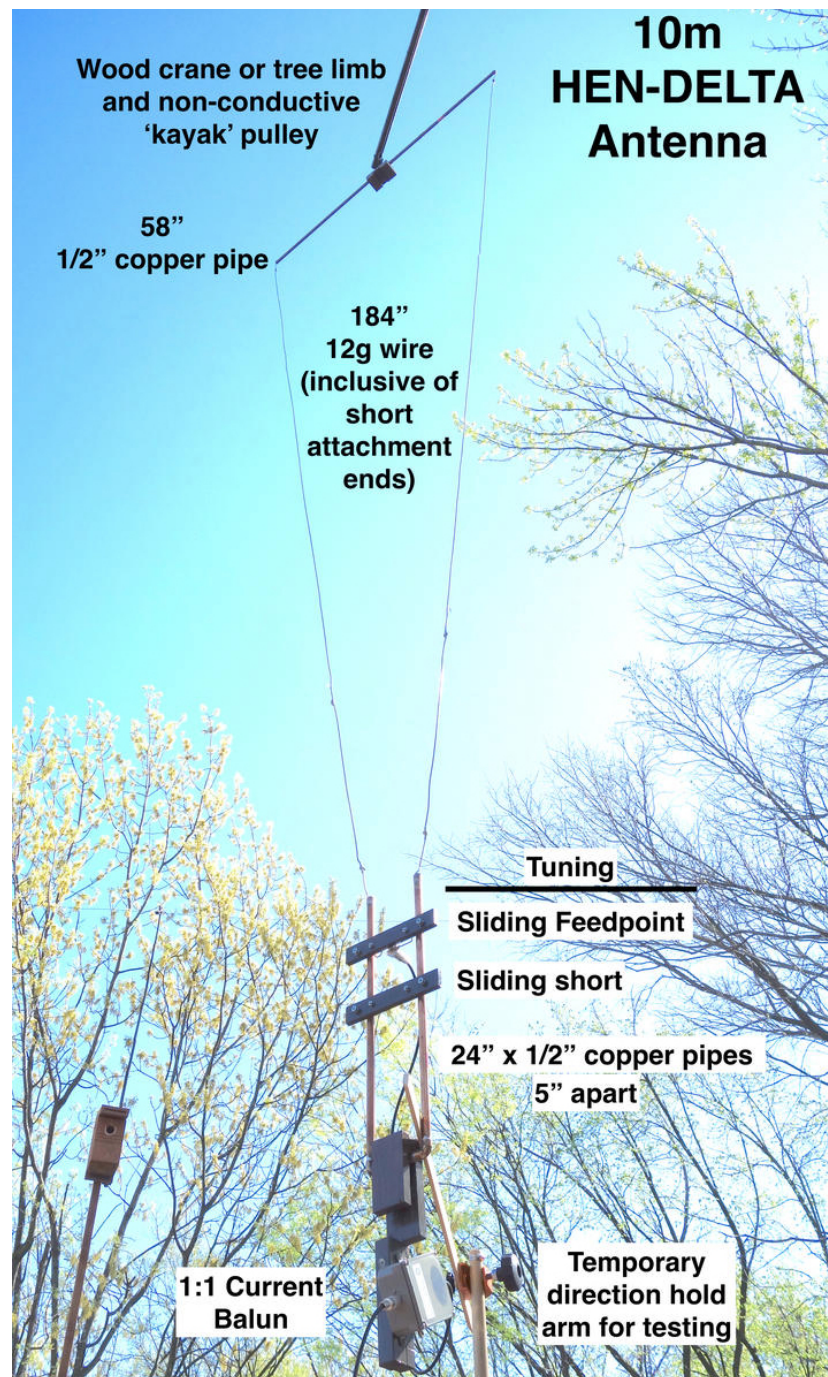
This little 10m antenna is about 5-feet wide at the top (thus it has a tiny 2.5-foot turning radius), about 17-feet tall, and is fairly lightweight (under 10 lbs) and collapsable (thus potentially transportable). It works well where horizontal space is limited but vertical space is plentiful – such as hanging from a tall tree limb or a non-conductive pole (like a fiberglass flagpole – and *nautical* flagpoles *do* have cross members near the top, just begging for a disguised Hen-Delta!). It is also very low visibility against a forest background, especially if the copper pipe is painted brown on the non-contact side. I used 12-gauge brown THHN for the 'down run' (or side) wires, but it does have a gloss to it. Ultra-flat dark brown spray paint matches tree bark here.



The antenna is bidirectional, very quiet, and seems to have a low take off angle, as is the nature of skeleton-slot antennas, and also based on DX performance. As you will see later, the 15m Hen-Delta is 3dB stronger than my 80m horizontal loop and is ~10dB quieter (thus it has ~13dB better signal-to-noise ratio *at my QTH*).

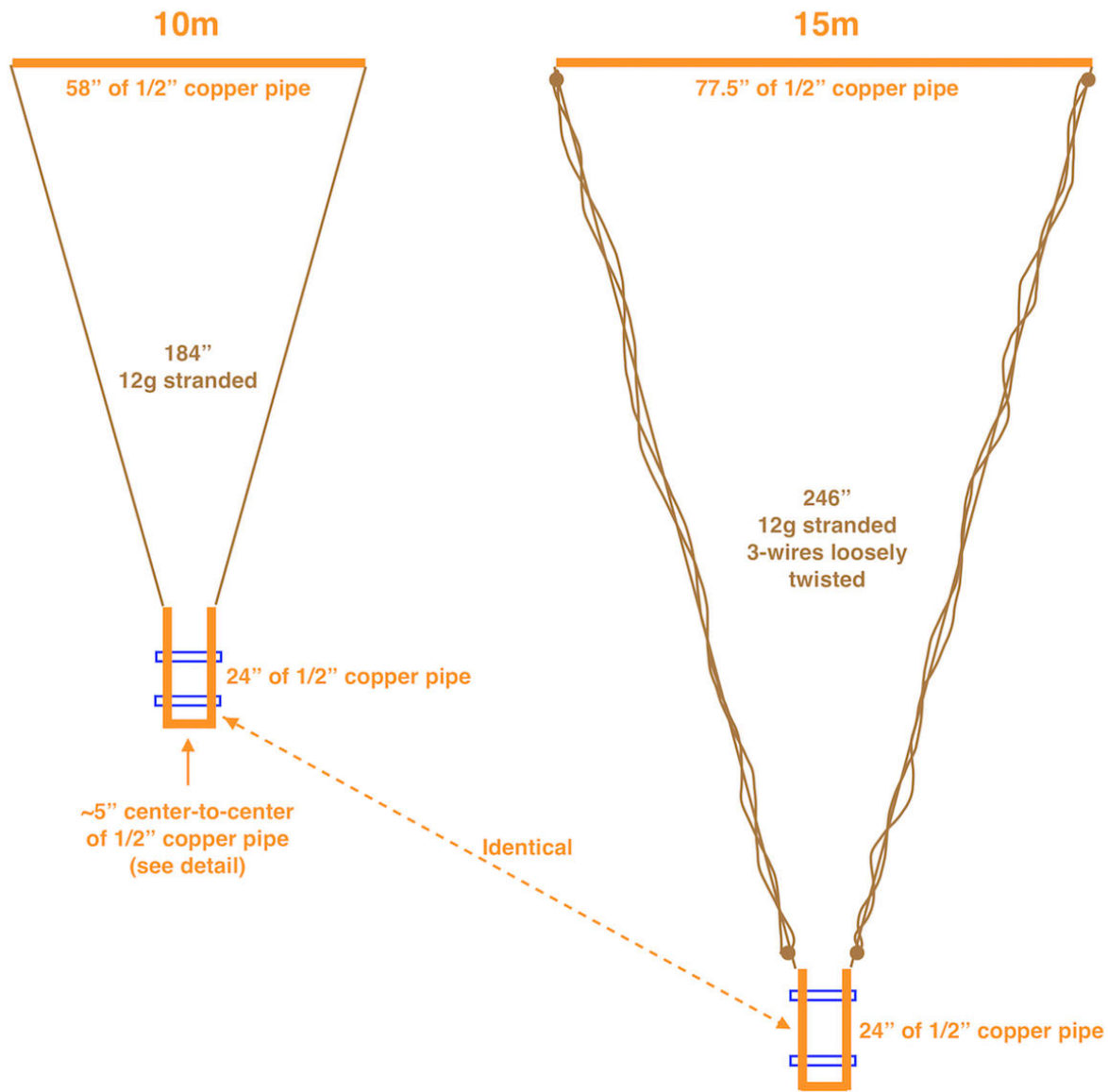
The 10m antenna's tuning stub as shown at right is about 3-feet above my wood deck, so about 12' above ground. Thus the radiating copper pipe is about 12' + 17' = 29' above ground. Or about 0.9 wavelengths above ground.

Left: A nautical fiberglass flagpole flying the ARRL flag... or a caged Hen-Delta in disguise? (Ans: Both!)



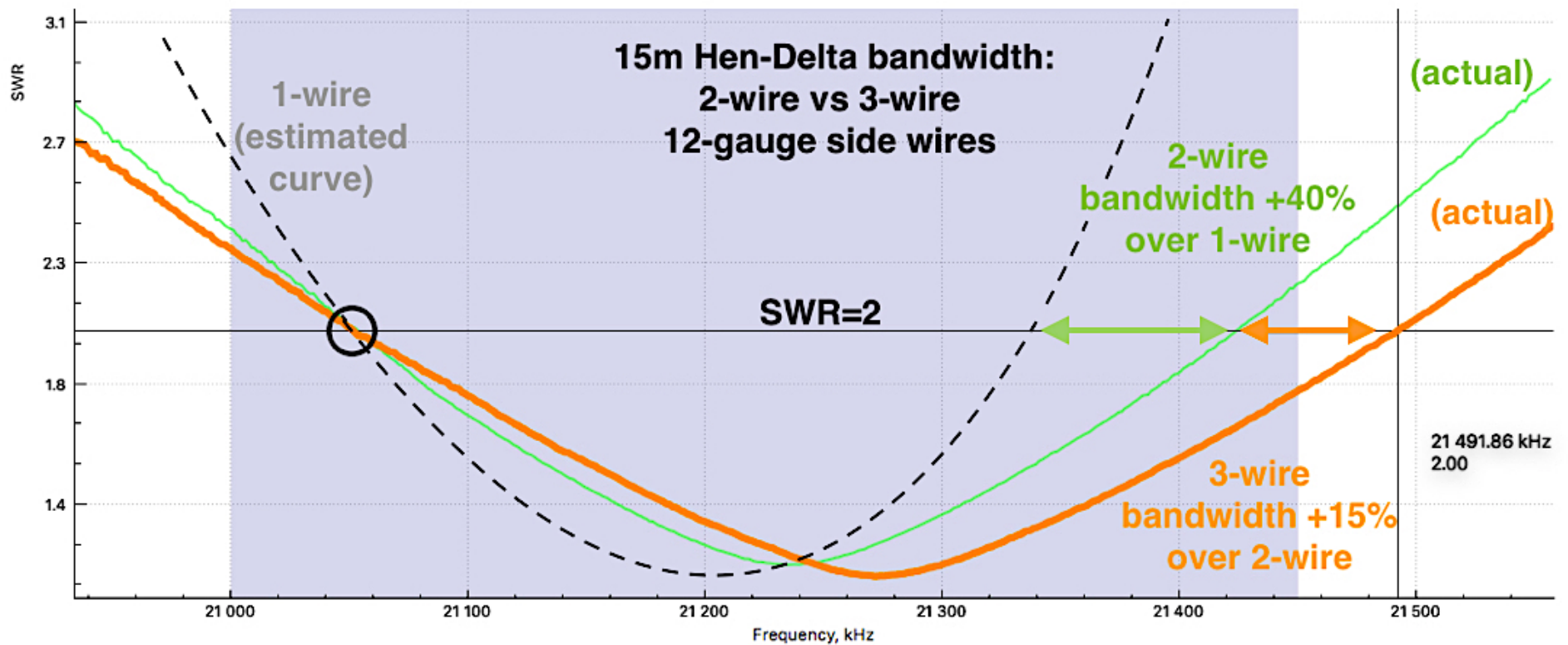
## (2) Early 10m and 15m Hen-Delta antenna dimensions:

2023: The 15m Hen-Delta shown here was the first *tentative* experiment with caging – using two, later three, loosely twisted wires to increase conductor diameter.



The SWR has been optimized for SSB above 21,200 kHz. The main point here is that a single-wire antenna (black dashed line) has such a narrow bandwidth that even loose extra wires as a rudimentary caging mechanism noticeably improves bandwidth.

Sample Palstar Tuner Settings for 15m Hen-Delta SWR graph above (3 'down wires'):



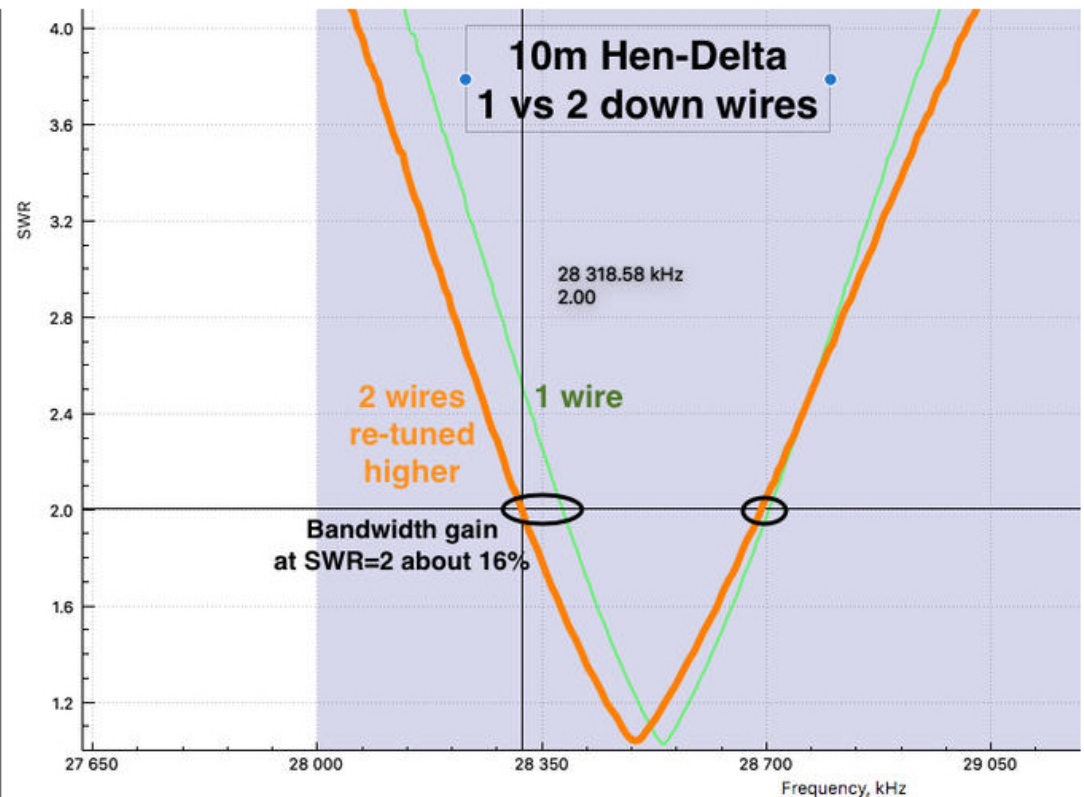
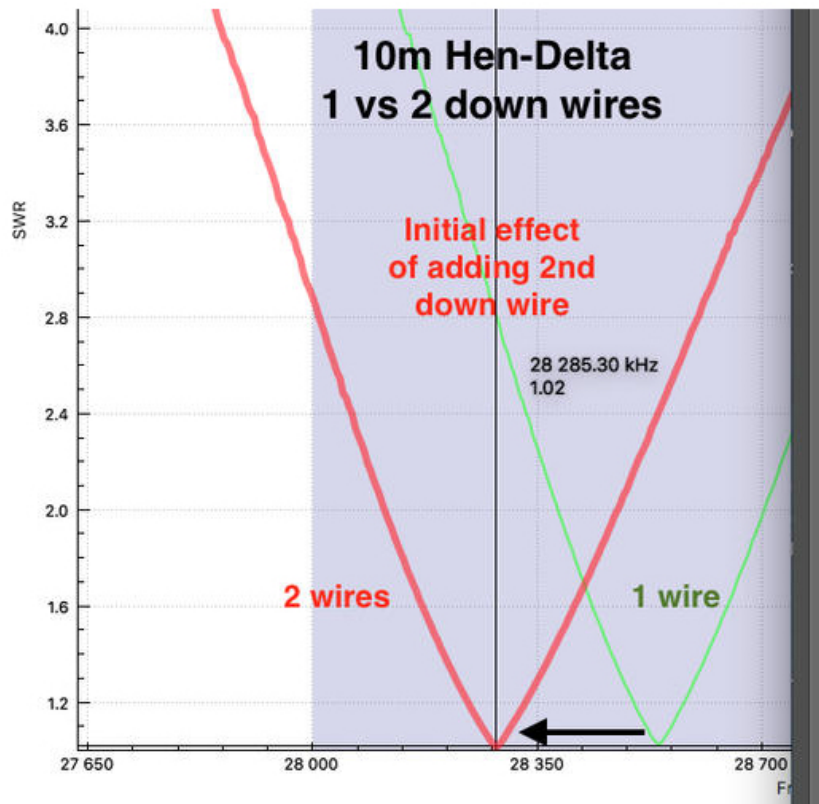
ERP (Effective Radiating Power or 'antenna efficiency') vs SWR: 1.0 = 100% 1.2 = ~99% 1.6 = ~95% 2.0 = ~90% 2.4 = ~83% 3.0 = ~75%

| Freq.  | C  | L   |
|--------|----|-----|
| 21,200 | 62 | 286 |
| 21,300 | 60 | 285 |
| 21,400 | 60 | 280 |

As you can see not much tuner tweaking is needed within the band.

2023-0606: The mornings test results from adding a second 12-gauge 'down wire' to each side of the 10m Hen-Delta. For positional stability the two wires were loosely twisted about 14 turns over 15', top to bottom. Initially the SWR curve was shifted lower by ~250 kHz – the first time I had noticed this 'center frequency shift' effect of caging, which can be quite significant. The antenna

was then retuned for the lower (and most popular) portion of the SSB frequencies. With only a modest 16% bandwidth improvement there was no motivation to add a third 'down wire'. **The nominal nature of this bandwidth improvement was likely due to the twisted wires being sufficiently tight on this occasion that the caging effect was minimized.**



ERP (Effective Radiating Power or 'antenna efficiency') vs SWR: 1.0 = 100% 1.2 = ~99% 1.6 = ~95% 2.0 = ~90% 2.4 = ~83% 3.0 = ~75%

Sample Palstar Tuner Settings for 10m Hen-Delta SWR graph above (with two 'down wires'):

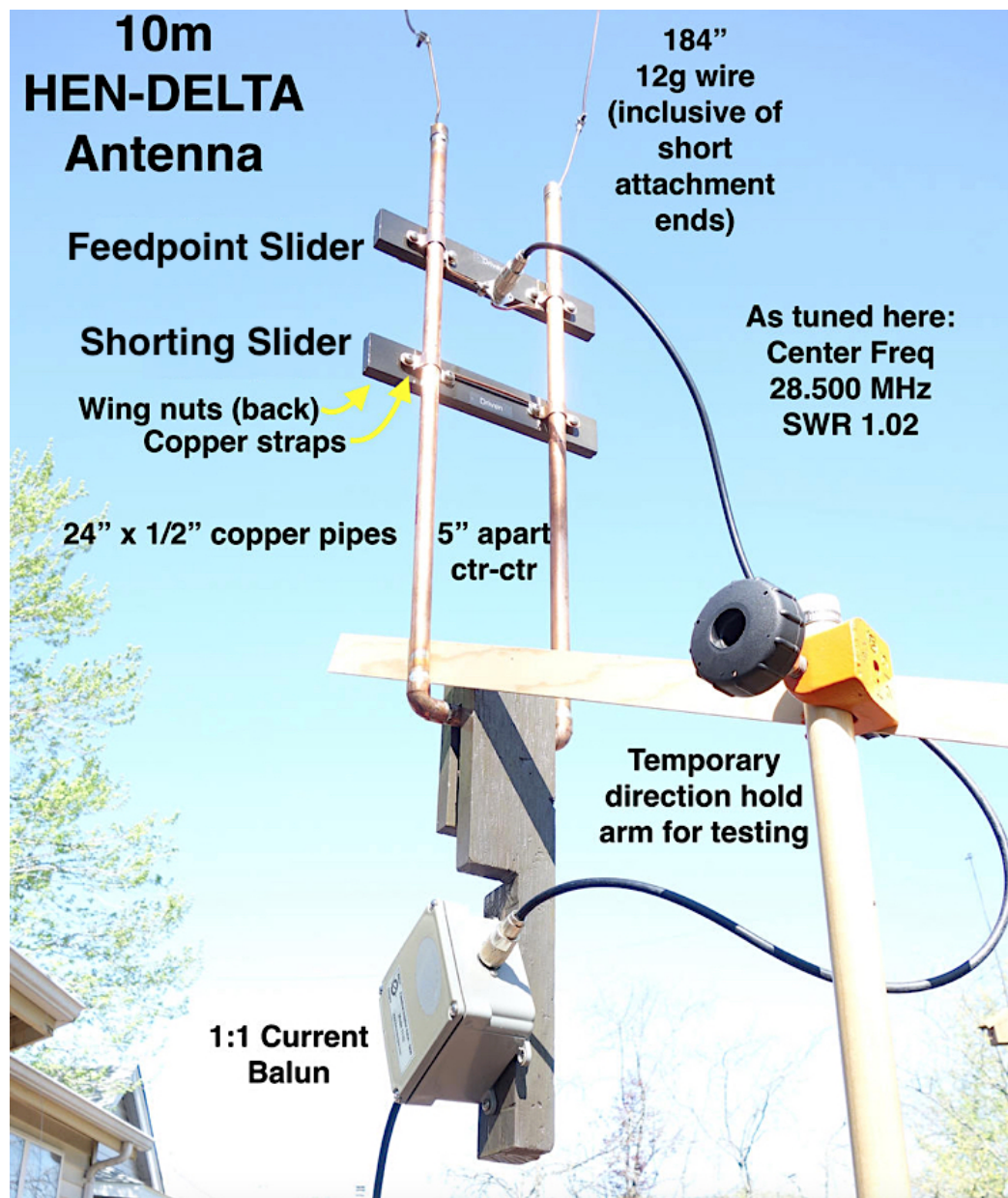
| Freq.  | C  | L*  |
|--------|----|-----|
| 28,350 | 73 | 293 |
| 28,450 | 69 | 286 |
| 28,550 | 72 | 284 |
| 28,650 | 76 | 284 |
| 28,750 | 78 | 284 |

\*The Palstar roller inductor counter is deliberately backwards for mechanical simplicity, so 299 is *minimum* inductance and 000 is *maximum* inductance. So a counter reading of 284 is very little additional inductance.

### (3) Early 2023 Tuning Stub (v1.0) Close-up:

#### Points to consider for photo at right:

- 1) You can alter the length of the 'down wires' or 'side wires' to relocate the final position of the two '**sliders**'. Make the down wires a few inches shorter to move the **feedpoint slider** and **shorting slider** a few inches lower on the copper pipe **tuning stub**.
- 2) A tuner is needed but doesn't need to be adjusted very often.
- 3) Use only stainless steel hardware.
- 4) When building the copper tuning stub I recommend using 4-3/8" (110mm) wood block spacers at top and bottom between the legs of the 'U' to keep them parallel while soldering the copper elbows in place while flat on a concrete floor. The sliding copper straps do tolerate some misalignment.
- 5) I recommend a more robust connection than shown at the top of the tuning stub to connect to the 'down wires'. This is discussed later.



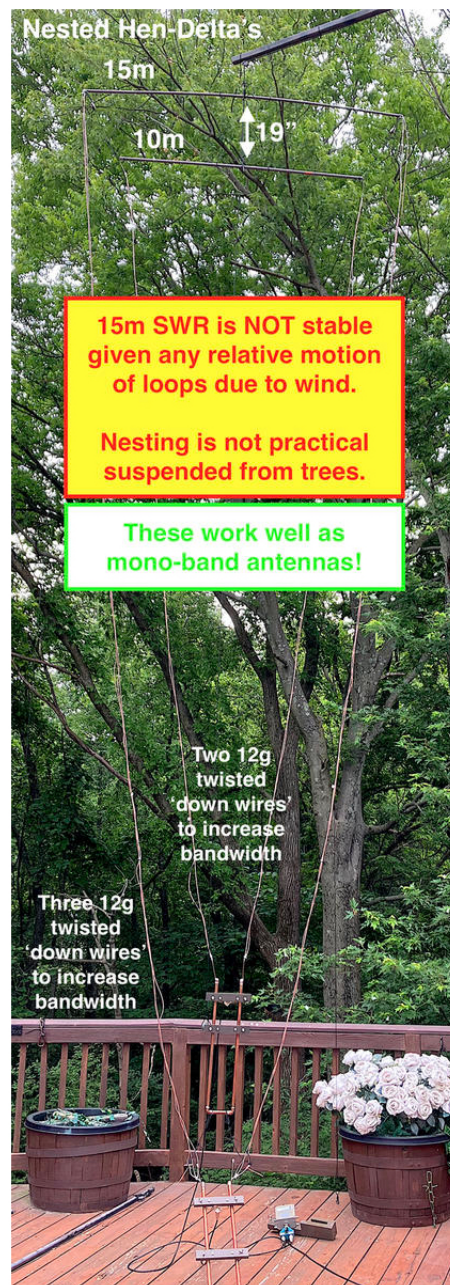
## (4) Nesting of Hen-Delta Antennas:

2023-0610: This was my first experimental test to see if the 'nesting' of 10m and 15m Hen-Delta antennas might be possible in order to permit a compact set of monoband Hen-Deltas to be suspended from a single pulley.

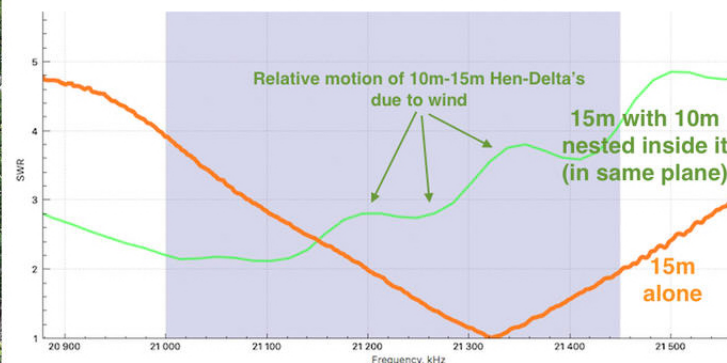
The separation between the antennas is maintained by lightweight cordage for testing. 15m appears to work just as well as when by itself and I worked a dozen operators in greater Europe and one in Mexico, all at 100W SSB. Signal reports today from Europe ranged from 55-59 with Mexico 59+10. The 10m band is not open as I write this, but I'll test it as soon as I can.

2023-0613: Nested 10m-15m Hen-Deltas suspended in tree 40 feet above ground. There was a stiff breeze today and I discovered that **ANY relative motion of the 10m and 15m Hen-Deltas destabilized the 15m SWR curve unpredictably (see graph at right)**. The 10m Hen-Delta, being on the inside, was essentially unaffected. ***Nesting only works if the two loops can be maintained in perfect relative alignment***, which isn't very practical in the field.

There are other ways to address this issue, described later.



SWR graphs showing 15m de-tuned by presence of 10m inside it



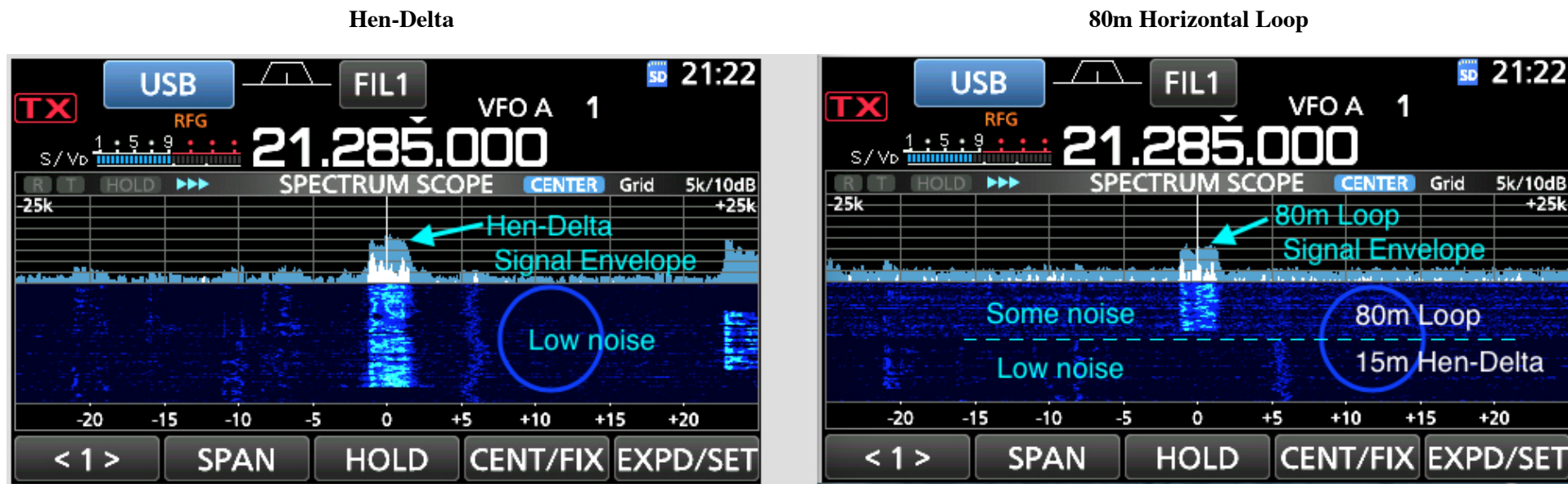
## (5a) Gain and Low-Noise Advantages of the Hen-Delta Antennas:

2023-0619:

- 1) The authors Portune and Bailey suggest that the Hen-Delta offers nearly 6dB of azimuth gain, or  $\sim 1$  S-unit. My subjective experiences with the Hen-Delta appear to support this. Partly this is due to the bidirectional nature of the antenna (azimuth gain), partly due to the horizontal polarization, but also to other factors which I do not completely understand at this time.
- 2) If you compare the 15m Hen-Delta's signal envelope (below left) rising up to almost four 10dB grid lines vs the loop's (right) signal envelope

rising up to three 10dB grid lines you will see that the Hen-Delta is  $\sim 10$ dB stronger. This was apparent while listening to the signal, as well.

- 3) Now compare the noise floors across the entire spectrum. The Hen-Delta offers a considerably lower noise floor, at least 3dB. Subjectively, including the low noise floor, it appears that the 15m Hen-Delta provides a 10dB + 3dB or 13dB better signal-to-noise ratio than my 80m loop. The loop's noise is probably city-related, thus rural amateurs may not see the same degree of noise improvement. Propagation had been stable for hours before these IC-7300 screen captures were taken.



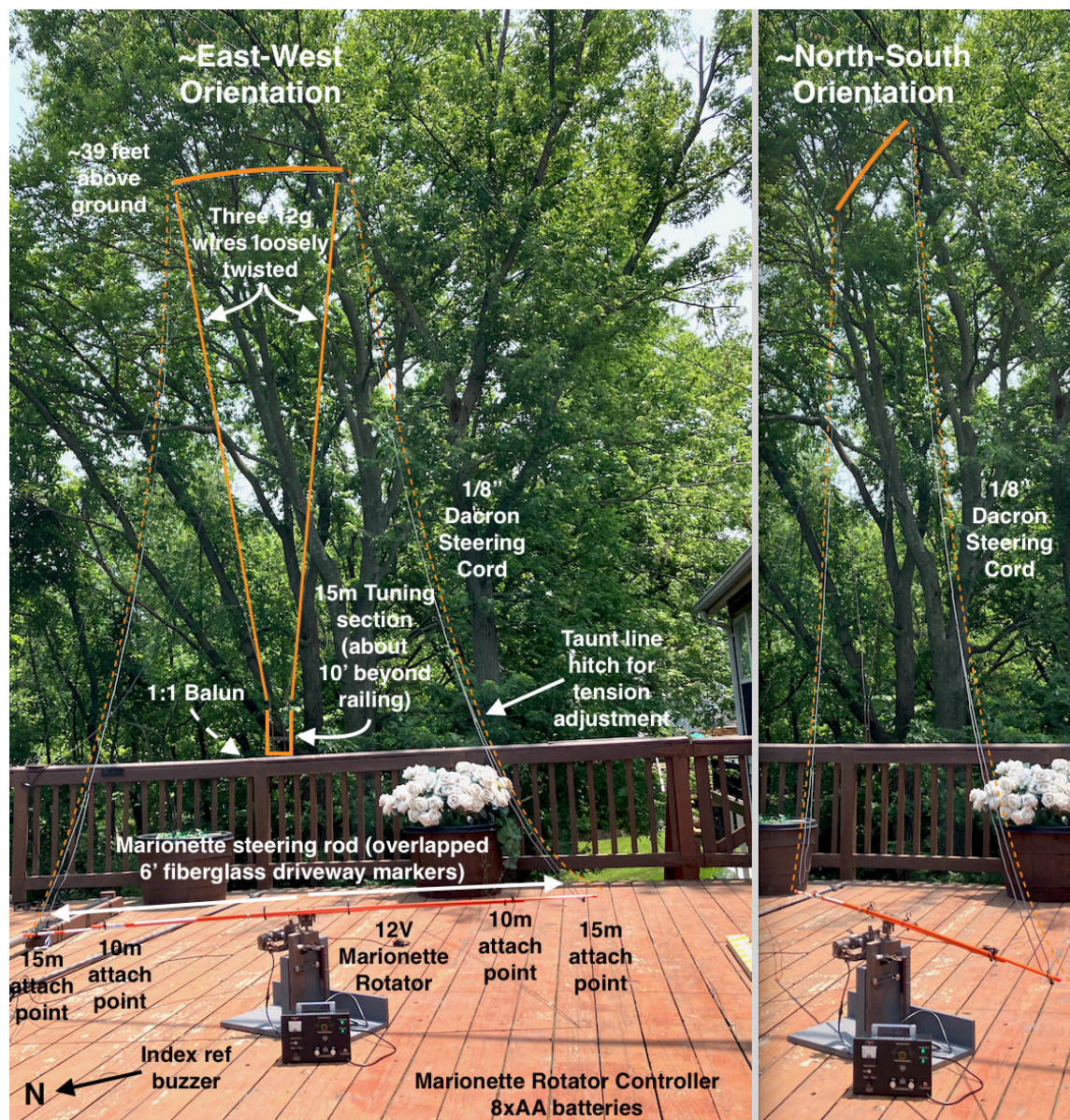
Test details: I used the coax switch on my Palstar AT2KD to switch instantly between the Hen-Delta and my 80m loop within seconds of each other for these screen captures. RF gain was untouched. The two antennas had C+L settings close enough to not need re-tuning – the Hen-Delta was specifically tuned and the 80m loop was thus very slightly off-perfect.

## (5b) Other Advantages:

- 4) Tuning is very easy once you learn how.
- 5) The Hen-Delta is physically narrow, reasonably light-weight, and can be deployed with a single rope. With the addition of an expensive copper union (see photo Chapter 23) at the center of the top copper pipe, the pipe could break down into two halves for easier transport.
- 6) The Hen-Delta can be rotated 90° by two Dacron 1/8" (3mm) cords attached to the ends of (or within) the copper pipe, either manually or with a home-made 'marionette' drive (shown at right), or by any mechanism which shortens one cord while lengthening the other – such as a linear actuator of reasonable length, say 36" or 0.9m. With the built-in limit switches of linear actuators, travel is stopped automatically. A DPDT polarity reversing switch selects  $\pm 12V$  to either extend or retract the actuator. Their are several way to accomplish antenna position feedback to the radio operator.

Note that the 6' fiberglass driveway markers were a good choice for this drive as I have seen them both flex almost 30" at their tips as gusts of wind blew the tree limbs around. If gusts increase the steering line force excessively then the base of the rotator drive will slide across the deck. See Chapter 22 for more marionette drive photos and discussion.

I use my tree-supported Hen-Deltas as 'fair weather' antennas, lowering them by 6'-8' to give the limbs more freedom of movement on windy days, or parking them (draped over the deck railing) when storms or high winds occur or are forecast. The PL-259 connectors for the antenna and balun need to be sealed or otherwise protected from rain, or water will eventually get into the coax. I view the coax as a 'wearing' component that will eventually need to be replaced – but the 10m outdoor run is still working well after 18 months.



15m Hen-Delta at 40' above ground in a tall tree, showing the use of a homemade 12V 'marionette' drive rotator. The controller shown (see Chapter 22) is located in the shack and is powered by the same power supply that powers the radio.

## (6a) DUAL & MULTI-BAND HEN-DELTA TUNING STUBS:

The Hen-Delta's tuning stub offers the unique and startling option of dual (or multi) tuning regions within a given band, or even dual (or multi) **band** operation. Let us first explore the simplest option of dual tuning regions, using the 10m band...

You will note that there are two *feedpoint sliders* and two *shorting sliders*. A feedpoint slider is by its nature 'open' if it is not utilized, so having a 'spare' feedpoint slider (or two or three) has no effect on the antenna.

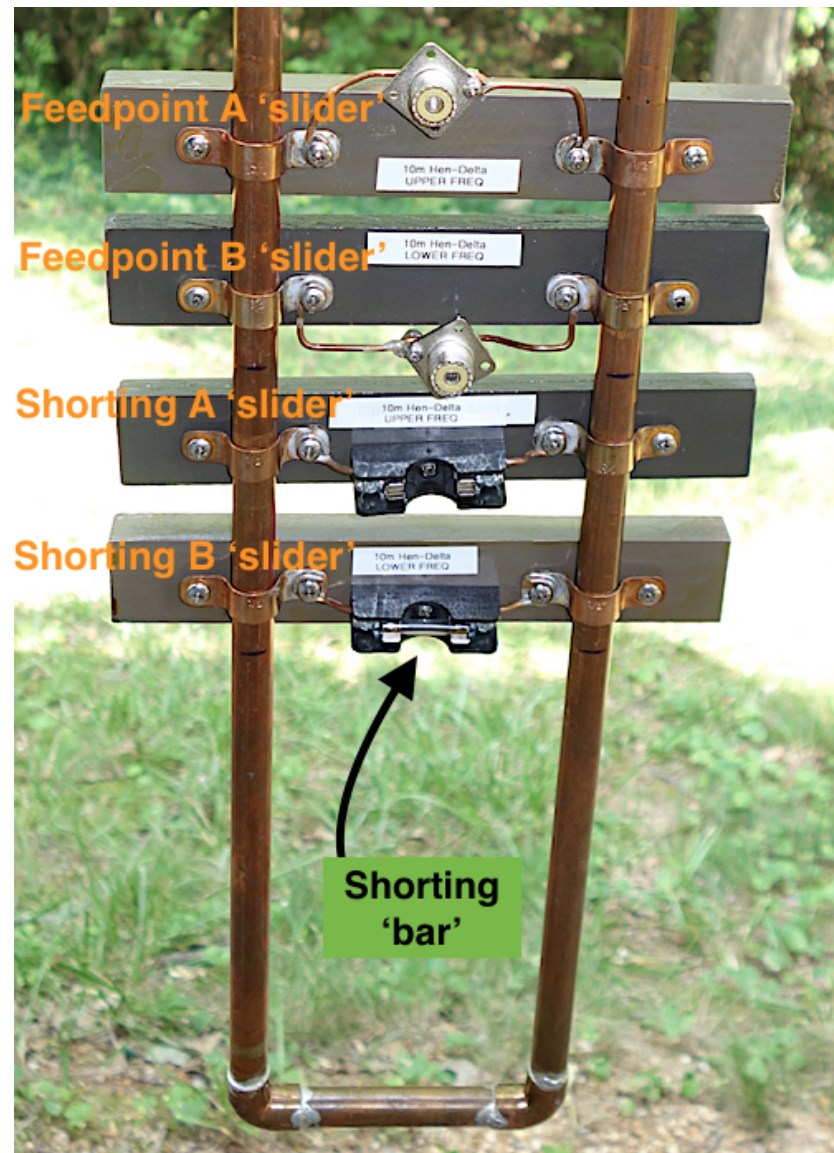
On the other hand, the *shorting slider* (not to be confused with shorting **bar** – a fuse in this build) would need to be switched open or closed. For expediency I used common 1/4" (6mm) fuse blocks and a 25A fuse. I selected a fuse with a straight fusible wire rather than a spiral-wound fusible wire so as not to introduce inductance into the path. Rather than a fuse you could easily substitute a 1/4" copper rod, a knife switch, another type switch, or a banana plug and jack. Any RF-friendly convenient switching method.

I didn't happen to think of it at the time, **but the bottom shorting slider need not be switchable. It can remain a permanent short.**

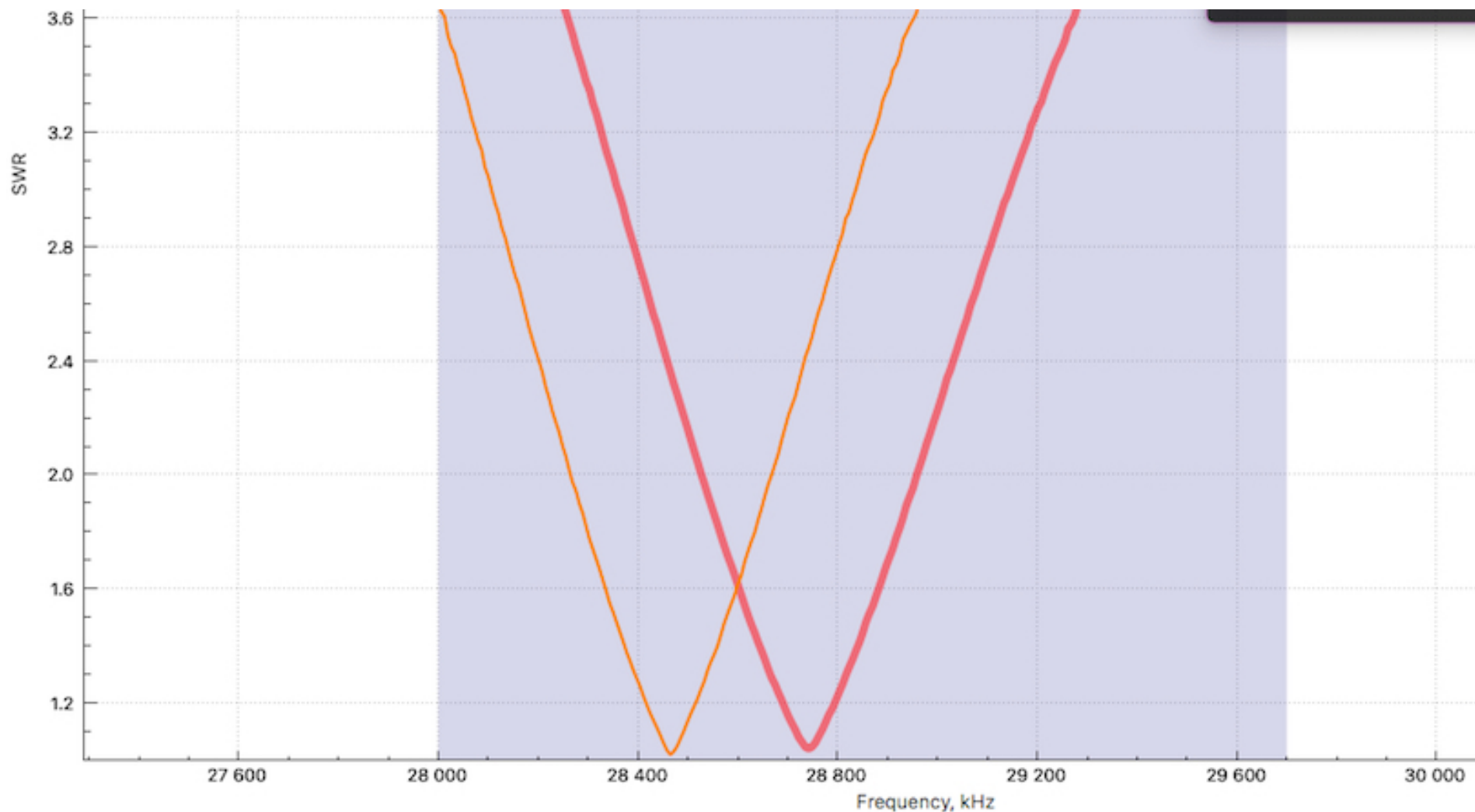
At right, the first and third sliders are a tuning pair, and the second and fourth a tuning pair. The two resulting SWR graphs (**pre-caging!**) are shown on the next page, one for the lower portion of the 10m band and one for the upper portion of the 10m band. These could easily have been tuned for the CW portion and SSB portion of the band, or to adapt to the antenna height above ground being 'high' (for DX) or 'low' (for local QSOs) – as long as the positions of the sliders themselves didn't chance to 'collide.' To work around slider collisions you could make the sliders structurally narrower in height, perhaps as narrow as 3/4", or build very wide 'compound' sliders with multiple contacts close together and then choose from among them (even remotely if using on-board relays). Such complex sliders could adapt to both band portion and antenna height.

Referring again to the dual-band photo at right, an obvious next step would be to add a SPDT coaxial relay for feedline switching and a single relay for Shorting Slider 'A'. Shorting Slider 'B' would be a permanent short. See Appendix-1 & -2 on multiple wavelength and remotely selecting bands.

The dual-tuning SWR graph follows...



Revision: the bottom fuse should be a permanent short.



ERP (Effective Radiating Power or 'antenna efficiency') vs SWR: 1.0 = 100% 1.2 = ~99% 1.6 = ~95% 2.0 = ~90% 2.4 = ~83% 3.0 = ~75%

Dual-tuning SWR graph: Orange is the lower SSB region (most commonly used) and red is the middle SSB region. If I had any skill with CW I might instead have tuned for CW and SSB curves. *These curves were made prior to any caging.* Because *height above ground effects tuning significantly*, the two tuning pairs could *alternatively* be utilized to cover the *exact same region of*

*the band*, but for *differing heights above ground!* One pair could tune for more regional, non-DX distances (low height above ground means high take-off angle) and the other could tune for DX distances (>1 wavelength above ground means a low take-off angle).

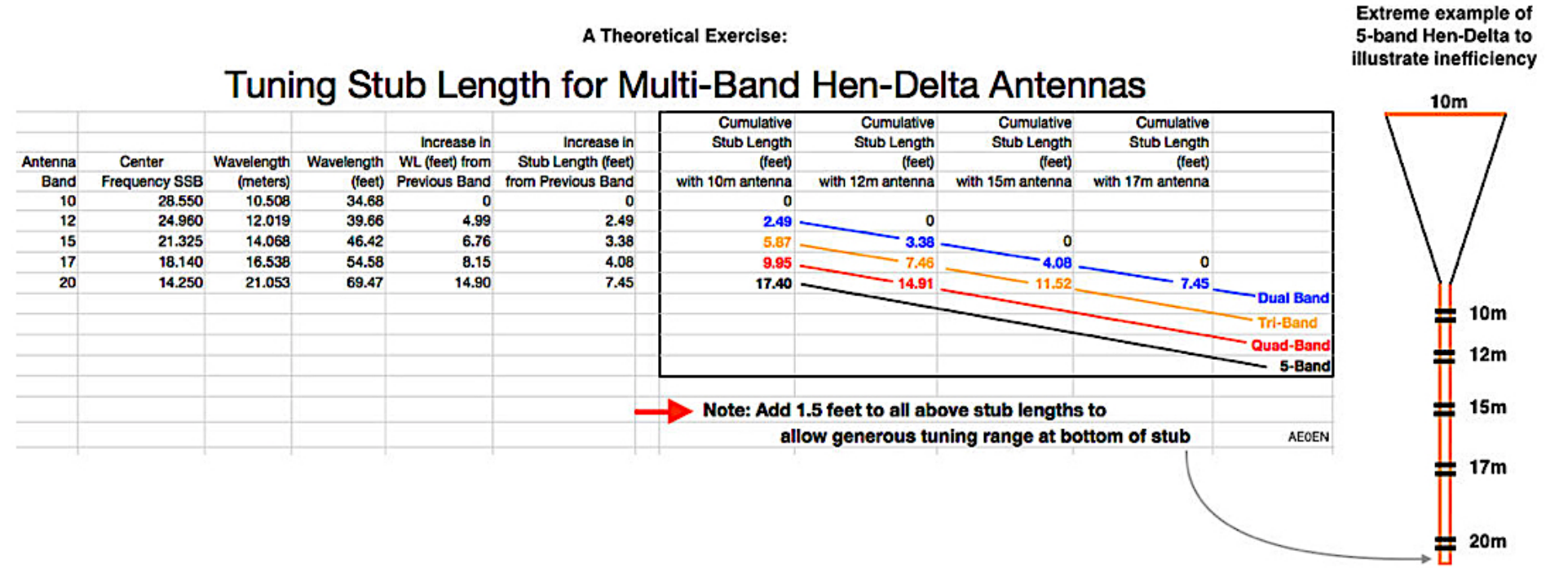
2024-0110: Having to swap out one Hen-Delta antenna for another is a bit of a nuisance, and I began considering the possibility of *dual-band* Hen-Deltas, as mentioned above. As you will see later, I actually did build and test a 10m/12m Hen-Delta using manual band switching – since I don’t need 12m very often. But this begs the question, how many bands can one Hen-Delta serve? In the extreme example to the right of the spreadsheet below you can see that the theoretical answer is: ‘as many as you wish’. But since each new band down the tuning stub uses the same sized ‘base’ antenna area as the uppermost one (10m in this example), you will experience a signal strength ‘opportunity cost’ on each successively longer wavelength band that you add. This is because each longer wavelength band would normally have a larger antenna area supporting it than the 10m provides. The top (10m) band will work normally, the next band down (12m) may lose 1-2dB (that’s a guess), 15m perhaps 3-4dB, and so on. If you want the simplicity of fewer mono-band antennas that is the trade-off *using this approach*. Intuitively, I suspect that the addition of just *one* adjacent longer

band would perform reasonable well – computer simulations by others may someday provide the answer.

For the 10m/12m Hen-Delta which I built, the actual tuned feedpoint slider-to-slider distance ended up at 24.25”. The chart below says the separation distance should be 2.49 feet (~30”), a 6” (20%) difference, so use this table only as a general guide. You can always trim the bottom of a tuning stub that is ridiculously long, but try to keep at least 18” of unused stub length at the bottom to accommodate future ‘downwire’ or caging changes.

See Appendix-1, -2 & -5 on multi-band and remotely selecting bands.

**2025-0525:** This page is obsolete. See Appendix-5 for a functioning 6-band Hen-Delta.



## An Actual DUAL-BAND 10m/12m Hen-Delta (3½” cage):

2024-0424: Having noted considerable activity on 12m by a recent DXpedition, I thought I would attempt to modify my 10m Hen-Delta to serve as a 10m/12m **Dual-Band** Hen-Delta antenna. To the best of my knowledge this has never been done before with a Hen-Delta antenna (except for my dual-region experiment above).

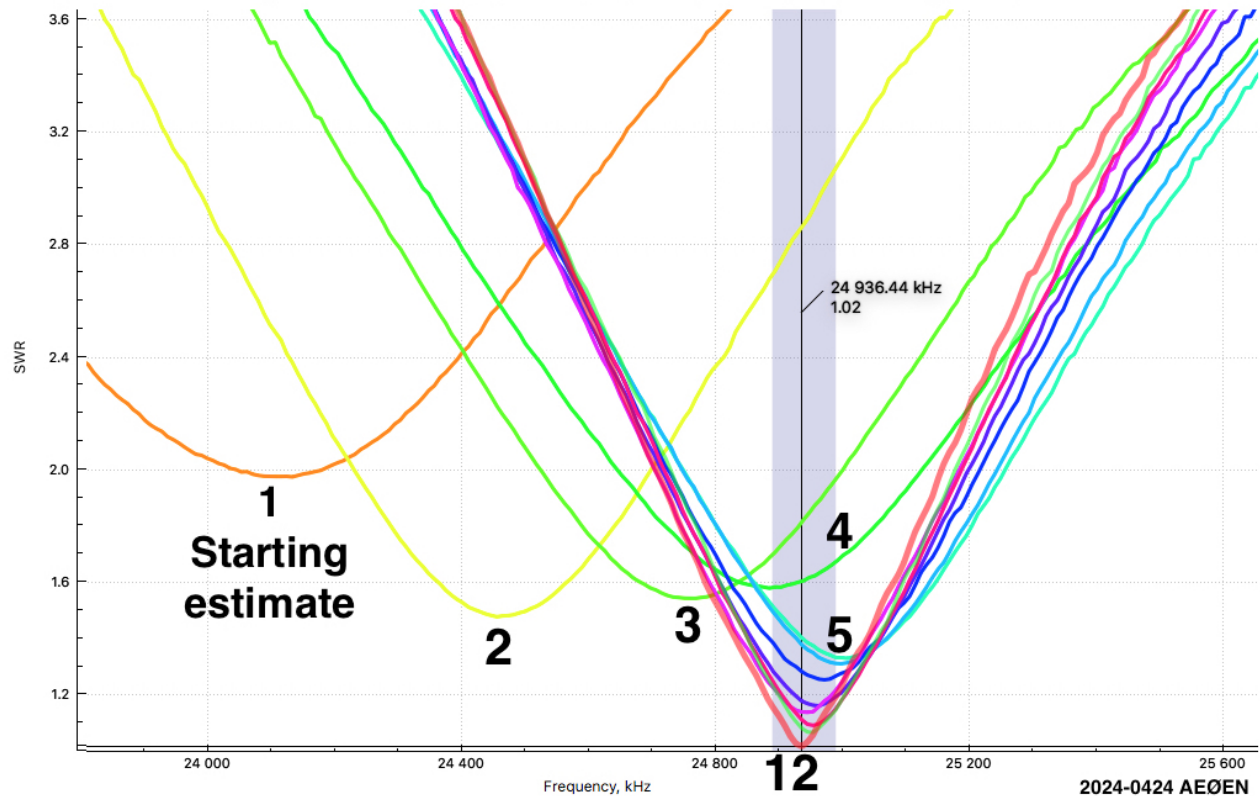
This also provides an opportunity to show the reiterative tuning process used to tune a Hen-Delta.

The first curve #1 shows the tuning process beginning with a starting ‘guess location’ for the two tuning sliders based on the table above. I typically move both the **feedpoint slider** and the **shorting slider** (using a nominal ~8” separation distance between them) until I shift the curve’s center close enough to the desired frequency. I don’t worry about the *depth* of the SWR minima during this process. Optimizing the depth of the SWR minima is achieved by moving the shorting slider only.

**Chapter 21 goes through the tuning process in great detail, step by step**, so I won’t go into it further here.

As you can see at right, the entire process took a dozen tuning steps before achieving a very satisfactory SWR minima of 1.02. The initial movement from curve 1 to 2 was about a 3” upward shift of *both* tuning sliders on the tuning stub to move the frequency higher (‘upward’ makes the loop a little *smaller*, so a little *higher* in frequency). The upward shifts from 2-3, 3-4, and 4-5 were roughly 2½”, 1½”, and 1”. Having gone a bit too high in frequency (a bit too far right at curve 5), I began moving the feedpoint slider downward on the tuning stub in increments of 1/2” to 1/4”. The final few adjustments were only 1/8” at a time. For the last

### Actual 12m Reiterative Tuning Process for 10m/12m Dual-Band Hen-Delta Antenna

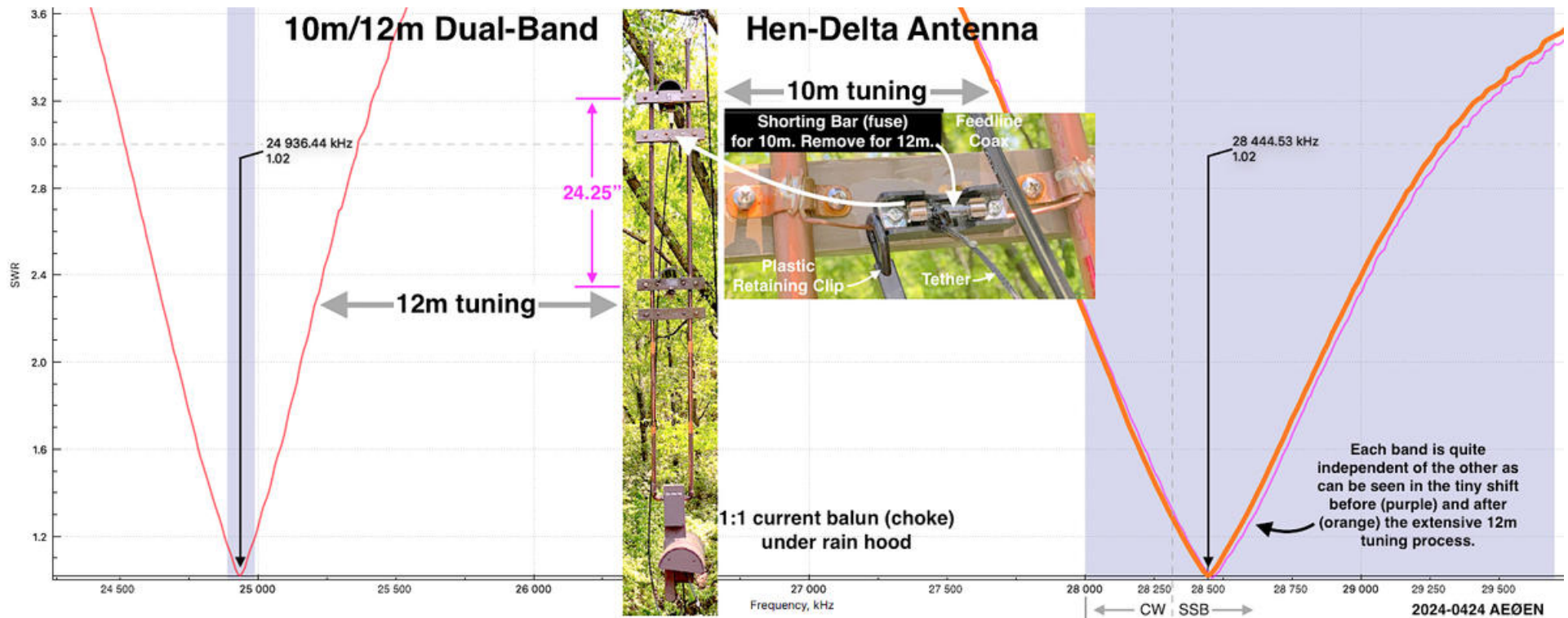


two steps 10-11 and 11-12 only the **shorting slider** was moved 1/8” to deepen the minima to almost 1.0.

Below are the 12m and 10m bands actually plotted on the same graph with some illustrations parked in the open space between them. **Only the 10m shorting slider has the removable shorting ‘bar’** (a 25A fuse, until I can replace it with a piece of 1/4” copper rod, shown two pages below). The shorting slider of the 12m band, being at the bottom of the tuning stub, has a permanent short – simply a 12-gauge wire.

The topmost band on the stub – 10m – was tuned first (the thin **purple** curve, below right), then the new, longer 12m band was tuned for the first time as just discussed (below left), then the 10m band (thick **orange** curve below right) was rechecked to see if it had been effected by the tuning of the 12m band. As you

can see there was no significant change and no need for any further tweaking of 10m. This result is very encouraging, indicating that *the bands of a dual- or multi-band Hen-Delta are independent of one another.*



It may be assumed that the longer band (12m in this case) of a dual-band Hen-Delta has about 1-2 dB less efficiency (that's a guess – I have no way to measure it) because the 10m 'base loop' supporting it is slightly smaller than it would be if it were a 12m mono-band Hen-Delta. Typically this slight decrease in efficiency will not be too noticeable on the first adjacent band...

...As confirmation of antenna functionality I had a QSO on 24.950 with a helpful Washington State amateur (distance ~1700 miles) who reported my 100W signal as '59' with excellent audio quality (which is the norm with the IC-7300).

Construction notes: Because the 20m band is so noisy here in the suburbs I very rarely use it, so I 'borrowed' the 5' tall tuning stub from that Hen-Delta to use for the 10m/12m experiment. The tuning sliders are the following distances below the top of the copper pipe... For 10m: 7.75" and 12.625", for 12m: 32" and 36". It is interesting to note that the feedpoint sliders for the two bands are separated by 24.25", where as previously mentioned, the 'multi-band tuning table' above suggests 2.49' (30"). This 6" shorter-than-predicted distance between theoretical and actual positioning is not too distressing, and someday I will look into it. Consider the table a rough guide.

## Building a fuse-sized shorting 'bar' to switch between 10m and 12m bands:

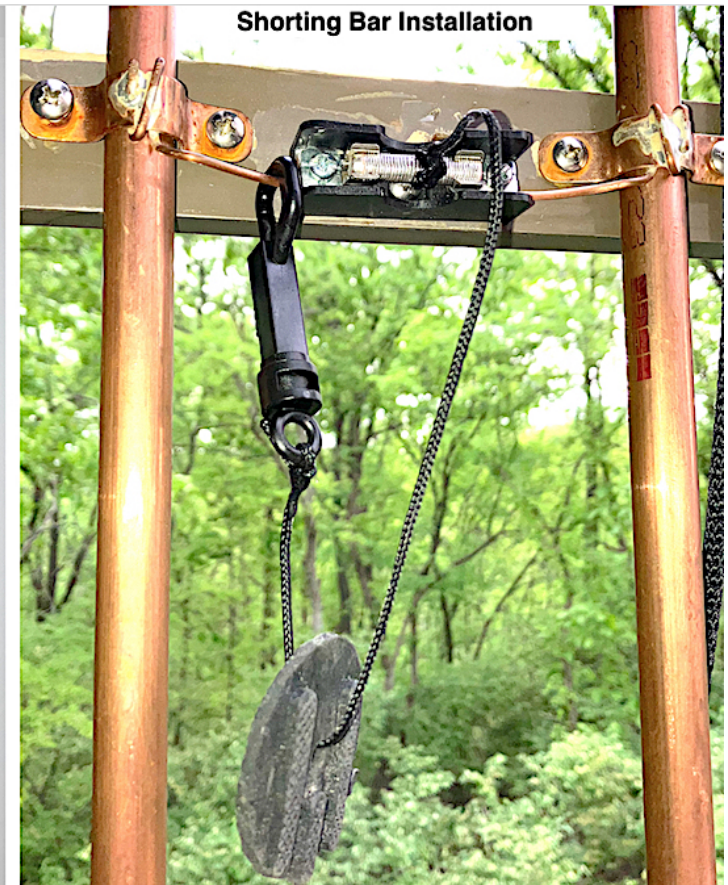
To use 10m band: Move feedline to 10m SO-239 feedpoint and **install** the 10m shorting bar.

To use 12m band: Move feedline to 12m SO-239 feedpoint and **remove** the 10m shorting bar.

I replaced the temporary 25A glass fuse with a permanent *shorting bar* made of 4-gauge solid copper wire (0.20" in diameter) wrapped in 22-gauge solid wire to increase the diameter. The entire wrapping was soldered together to make a non-inductive conductive cylinder of about 0.25" (~6mm) diameter.

A small Dacron cord was tied and glued to the shorting bar so that it wouldn't be dropped and lost. The plastic clip and the 2" rubber 'washer' allow the shorting bar to be removed and hang loose from the shorting slider, conveniently available for future use and without any 'wind chiming' from the shorting bar being blown against the copper pipe by the wind.

See Appendix-2 on remotely selecting bands.



## (6b) Sidebar: ‘Trombone’ Variable Length Antenna Element:

2024-0225: This experimental variable-length top element was built but has not yet been placed in service. Some may find it useful on its own merits. It might also allow easier transportability of a portable antenna.

**Construction:** During all soldering steps take care that you don’t melt previously soldered parts and joints! Separate the sliding pipes so that there are a couple of feet of distance between to-be-soldered and already-soldered points! Use just the minimum amount of solder needed – it must not pool inside the  $\frac{3}{4}$ " pipe.

Take great care in the order of construction and dry fit parts and assemblies before soldering them.

The soldered wire-wrapped coupler on the  $\frac{1}{2}$ " pipe (internal to the  $\frac{3}{4}$ " pipe when installed) increases its diameter and makes for a less sloppy fit than the coupler alone, but it isn’t really a ‘tight’ fit and doesn’t need to be – it’s just there for better internal cantilever support.

Note that most  $\frac{1}{2}$ " to  $\frac{3}{4}$ " adapter couplers have an internal stop (‘bump’ or ‘ring’) which must be filed off completely so that the  $\frac{1}{2}$ " tube can slide through it. This takes some time and patience.

With a hacksaw cut a pair of thin slots (two gaps) into the  $\frac{1}{2}$ " end of the  $\frac{1}{2}$ " to  $\frac{3}{4}$ " reducer (adapter). These two slots (gaps) allows the hose clamp to squeeze the  $\frac{1}{2}$ " reducer end tightly closed and grip the  $\frac{1}{2}$ " pipe, preventing the trombone from moving. A second hose clamp also prevents the  $\frac{1}{2}$ " pipe from being pushed (compressed) into the reducer. This is an RF connection.

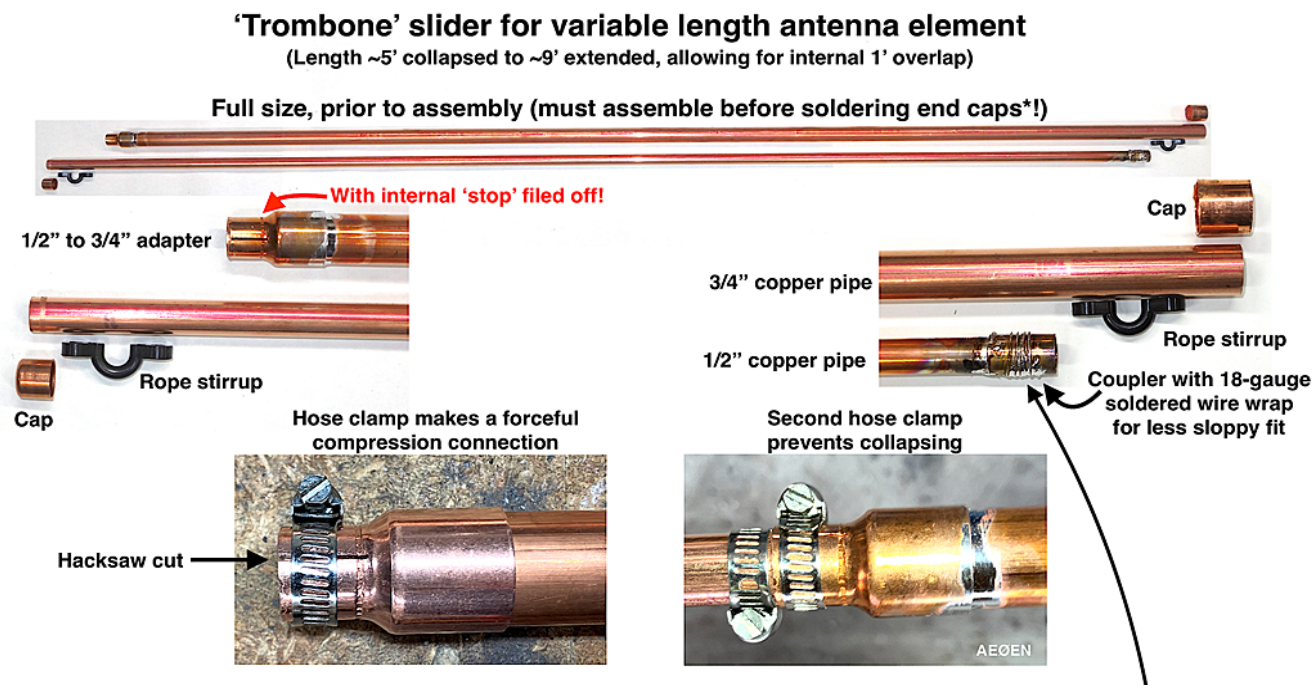
Carefully solder the now-slotted reducer to the  $\frac{3}{4}$ " pipe. Let it cool.

Slide the  $\frac{1}{2}$ " pipe into the  $\frac{3}{4}$ " pipe from the far open end and out the  $\frac{1}{2}$ " open end of the reducer.

**Do nothing else until the two pipes are nested and sliding within each other or you won’t be able to slip the  $\frac{1}{2}$ " pipe inside the  $\frac{3}{4}$ " pipe!**

Once the two pipes are nested, drill  $\frac{1}{16}$ " weep holes on the bottom somewhere near the future rope padeye (stirrup) locations – the padeyes (stirrups) will keep the  $\frac{1}{4}$ " Dacron support ropes in place, but do not mount the padeyes yet! Solder on the end caps. Then drill the end caps with a  $\frac{1}{8}$ " bit and solder on 4" 8-gauge solid copper leads (pigtailed) with 2-hole lugs for connections, not shown below but as seen elsewhere in this document.

When the copper pipe ends have cooled attach the padeyes with short stainless steel screws.



\*Note: Extend  $\frac{1}{2}$ " trombone pipe >20" BEFORE soldering on  $\frac{3}{4}$ " end cap to PREVENT ACCIDENTAL MELTING of nearby wire-wrapped coupler solder!

## (7) Minimum separation distance between Hen-Deltas on a common boom:

2023-0620: This experiment involved clamping together overlapping 2x2's to make a long boom and then clamping it to a ladder as shown on the next page. The copper pipes of the two Hen-Deltas were thus at the same height above ground. **Moving the ladder back and forth on the wooden deck varied the separation distance between the 10m and 15m Hen-Delta top elements.** A weighted, marked string was tied to the moving 10m copper pipe and hung over the 15m copper pipe, thus measuring the exact separation distance as the ladder was moved. In this manner the minimum separation distance with respect to tuning (and by implication operation) of the two Hen-Deltas on a common boom can be determined.

The stationary 15m was the active antenna for SWR measurements. Previous experiments showed that when nested in the same plane the 10m SWR curve was almost unaffected by the proximity of the surrounding 15m antenna, thus the 15m antenna is the most sensitive of the two with respect to detuning by the smaller antenna. The normal operating height for any Hen-Delta suspended from my tree is 39-41 feet and that is too high for us to reach for this kind of test, so the 15m Hen-Delta was lowered about 12 feet such that its tuning stub was just 2.5 feet above ground. As you can see in the photo on the next page this put the two antenna's **top elements** (copper pipes) at the same height. In graph (a) you can see that lowering the 15m Hen-Delta shifted it slightly to point-'b'. Since we are only interested in the *relative* change of the curves vs separation, the curve being slightly detuned isn't important.

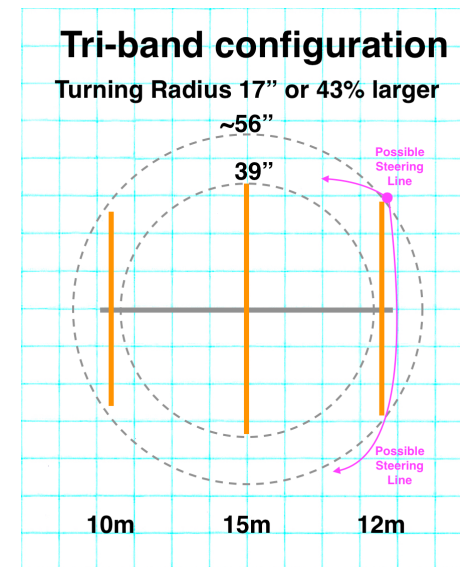
In graph (c) you can see about ten of the 15 total test runs made. Some tests were deleted as the graph was getting too busy and they were all on top of one another. A few tests involved deliberately introducing rotational oscillations in the 10m Hen-Delta to see how the relative movement affected SWR. There are interesting lessons present in the graphs. Note that separation distance had to be reduced to 2 feet before the SWR curves showed serious detuning, at the gray ellipse (point 'd'). All of the 3-foot, 4-foot, 6-foot, and 8-foot curves more-or-less coincided and had the same minima (point 'e'). There was only one test of the top element's copper pipe movement or oscillation (yellow trace) at 2', and its effect was dramatic, so 2' is definitely too close together.

**Conclusion:** It is possible to have 10m and 15m Hen-Delta antennas share a non-conductive boom and not significantly alter either antenna's tuning. The

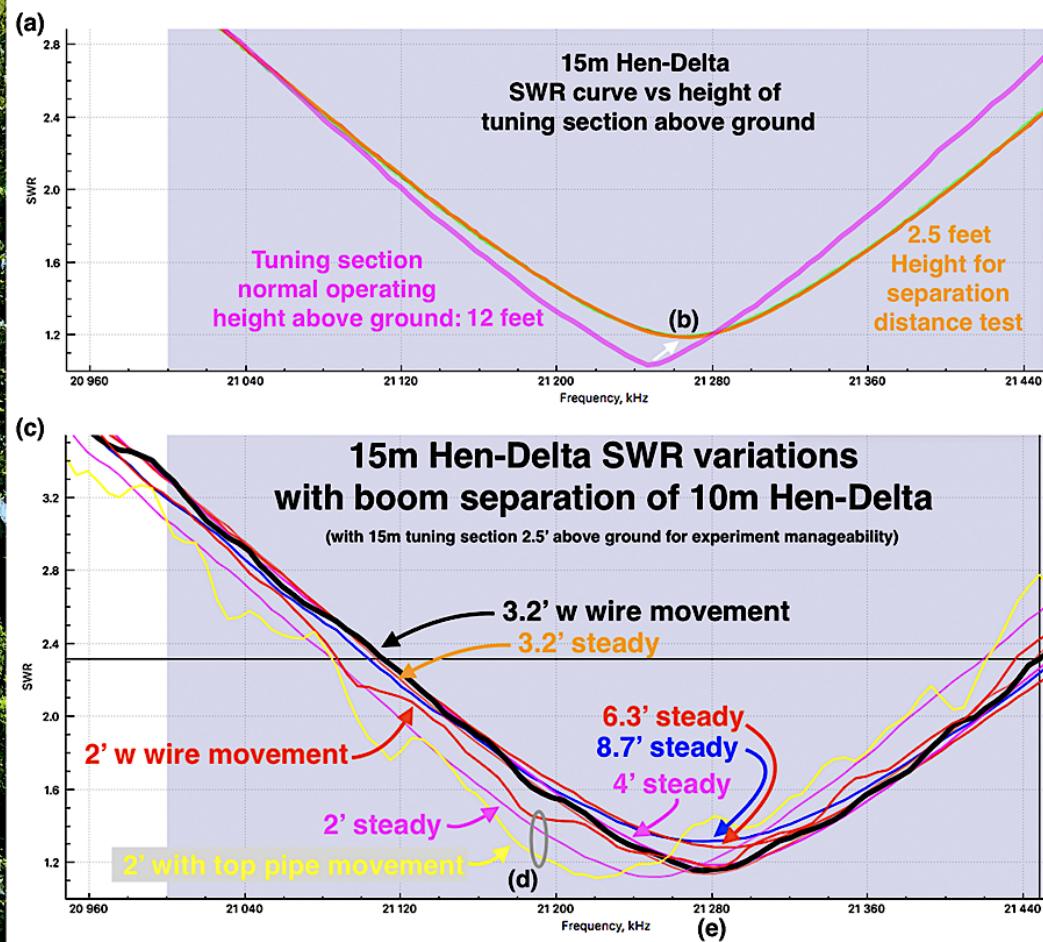
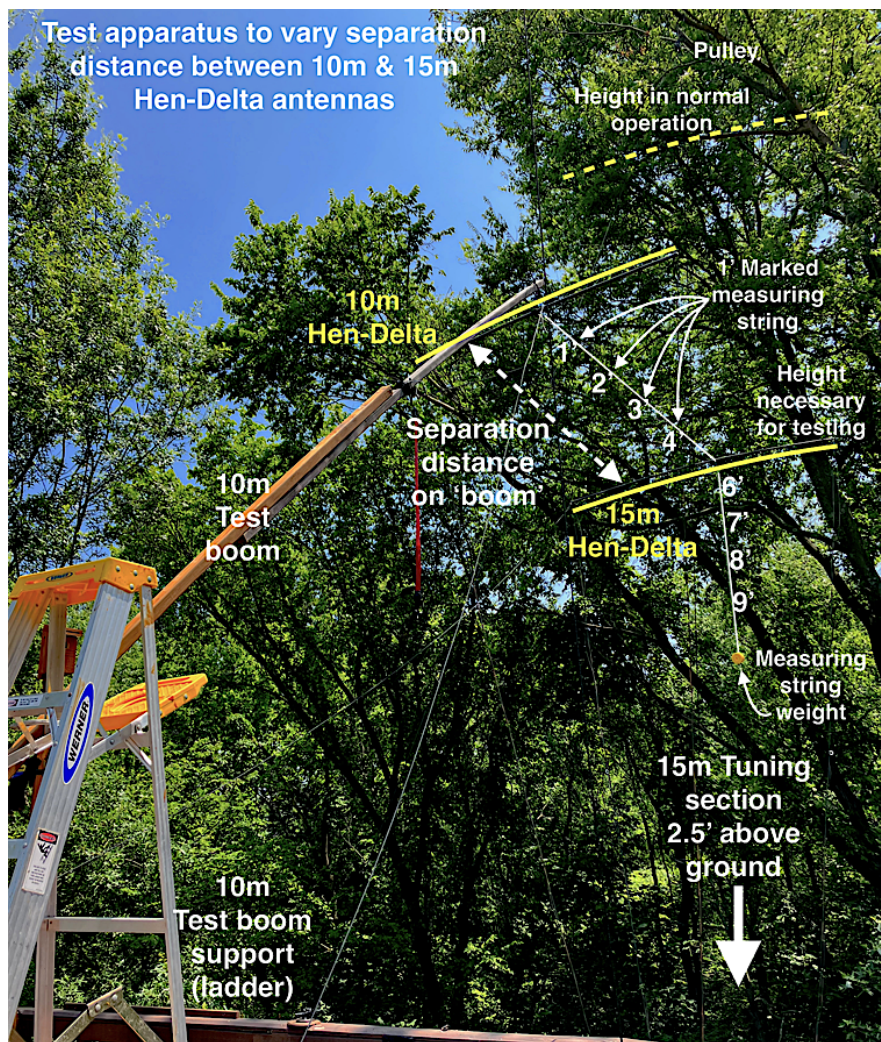
*minimum* boom separation is probably ~3.5 feet or 1m. The copper pipes need to be secured to form a fairly rigid 'H' shape the width of the 15m copper pipe (~78") by the depth of the boom (~42"), or about 6.5x3.5 feet, or 2m x 1m. That is still a fairly small horizontal footprint and preserves a relatively small turning radius.

To prevent non-parallel pendulum sway the two antennas' *tuning stubs* should be interconnected with rigid rods such as 6' fiberglass driveway markers. A little parallel sway in the wind shouldn't be too disruptive, but no doubt other cross-bracing or ground-tethering could be provided to reduce motion further – depending on the wind speed of concern.

My son and test collaborator, David AE0IZ, has suggested that there is room for yet a third Hen-Delta on the opposite side from the 10m to create tri-band configurations like: 10m-15m-12m or 10m-20m-15m, etc. The turning radii of such sets are only slightly larger than the center antenna's top element (right). Configurations of two *dual-band* antennas like 10m/12m-15m/17m are plausible. Modified steering lines similar to those now in use could wrap around the conical volume, easily offering 180° of rotation (magenta lines at right). The drive location would be well to the left of this illustration.



Each antenna would need either need its own 1:1 current balun or a remote switch would have to be employed on the antenna side of the balun to select the band to be used. With the exception of the brief Hen-Delta-yagi experiments in Chapter 10 below, I have not attempted a permanent multi-antenna boom mount – primarily out of concern for the long term weight on my 2" tree branches.

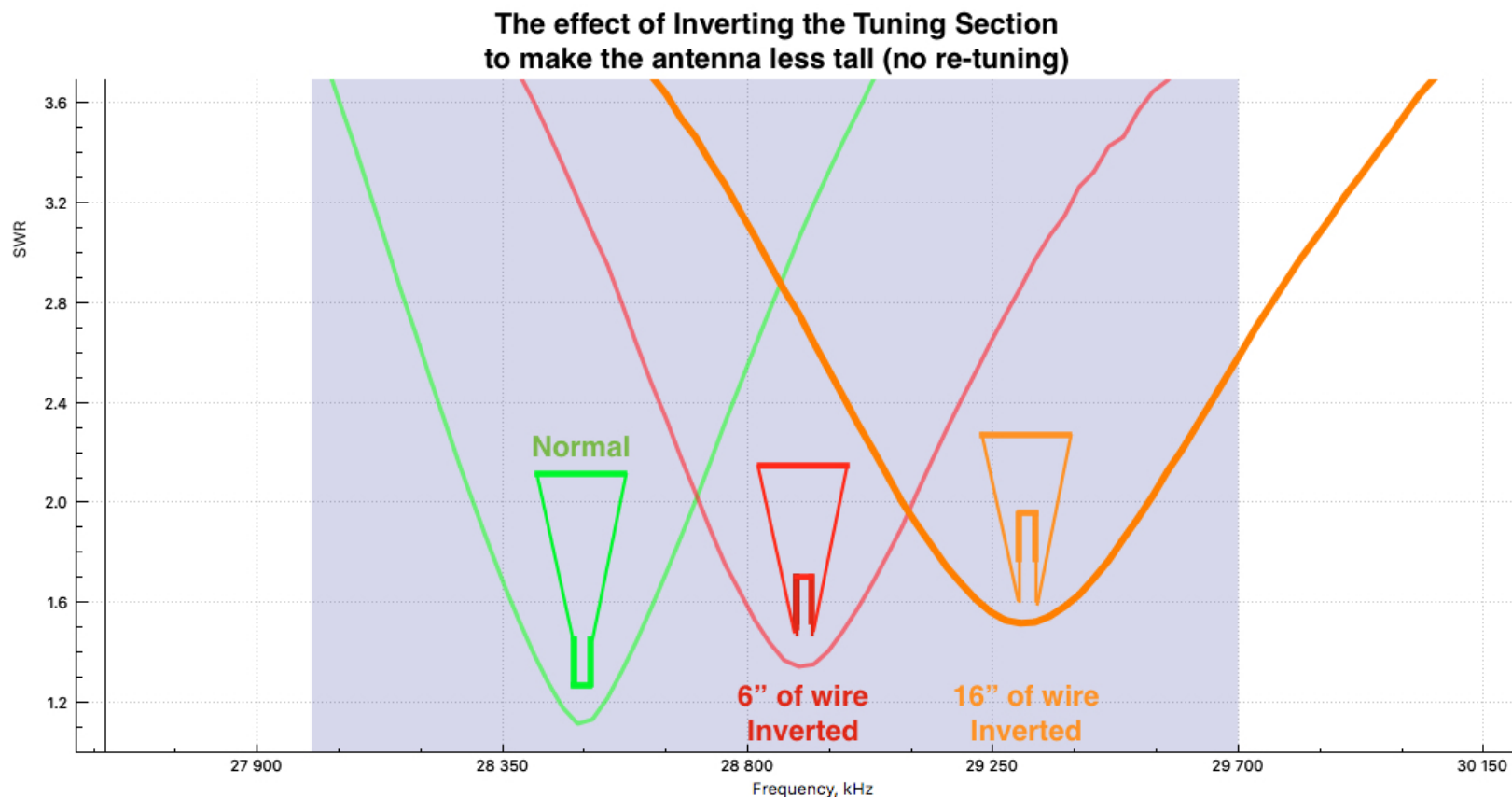


Experimental test jig to vary distance between 10m and 15m top elements and study tuning interactions.

## (8) Inverting the Tuning Stub to Reduce the Hen-Delta's Overall Height:

2023-0621: This was not an exhaustive test but I wanted to see if the idea was plausible – and it *is*! The 10m's **tuning stub** was inverted (see sketches within the graph below) with about 6" of wire below it (**red curve and sketch**), then again with about 16" of wire below it (**orange curve and sketch**). The SWR curve shifts upward dramatically – about 500kHz each test – but appears otherwise well behaved. This suggests that, with re-tuning, the inverted tuning stub modification is quite possible. In the first (red) test the overall 10m Hen-Delta height was shortened by 14%, in the second (orange) test by 19%. It would be interesting to simulate this effect in software to see just how short the antenna

could be and still perform well, but that is beyond my skill presently. I strongly suspect that the tuning stub, if in the *interior volume* of the antenna, would need to be mechanically stable so that there was no relative movement with respect to wires or the top copper pipe. But this might also be easily addressed. I did not attempt to retune these inverted tuning stubs because I didn't want to discard the correct 'upright' tuning and then restore it later, simply to briefly test the inverted tuning stub concept. So while tuning the inverted tuning stub to an SWR near 1.0 was not attempted, I have no doubt it would be successful. Since a shorter vertical height isn't important to me, I didn't pursue it further.



## (9a) Effect of Caging Hen-Delta ‘down wires’ (side wires) on bandwidth:

2023-0711: In preparing a **reflective element** for a two-element Hen-Delta **yagi** experiment I found I wasn't pleased with the reflector's bandwidth. With the Hen-Delta (and all antennas, really) it is important to keep the elements from moving relative to one another, and I had used spiral cable wrap (green line on the chart below) to keep the three unruly ‘down wires’ captured — but it worked too well, reducing the caging effect, and bandwidth suffered. Looking for a plastic disk of some kind with which to try ‘real’ caging, I stumbled into these polypropylene load spreading ‘washers’ on Amazon (\$8 for 100) whose small holes, by chance, are just the right size to snugly fit my 12-gauge hardware store THHN stranded wire (see inset photos on next page).

I understand now *that there are much better caging solutions* (see Chapters 14-19 below) but at this point in time (see date stamp) at under SWR 3 for the entire 15m band, this at least offers acceptable results for the purpose of testing a reflector. The driven element was also caged the same way. This is a 1.1” cage (0.28% of wavelength).

**This was my first *serious* attempt at true ‘caging’... (next page).**

**NOTE:** This SWR chart is for a 15m *reflector element* tuned to a *5% lower frequency* (a larger element) than the normal 15m band.

## Result of caging 15m Hen-Delta 'down wires' on bandwidth

Note: Allowing for green SWR curve not being optimized to the same minima, derate caging benefit to about +50 gain in bandwidth.

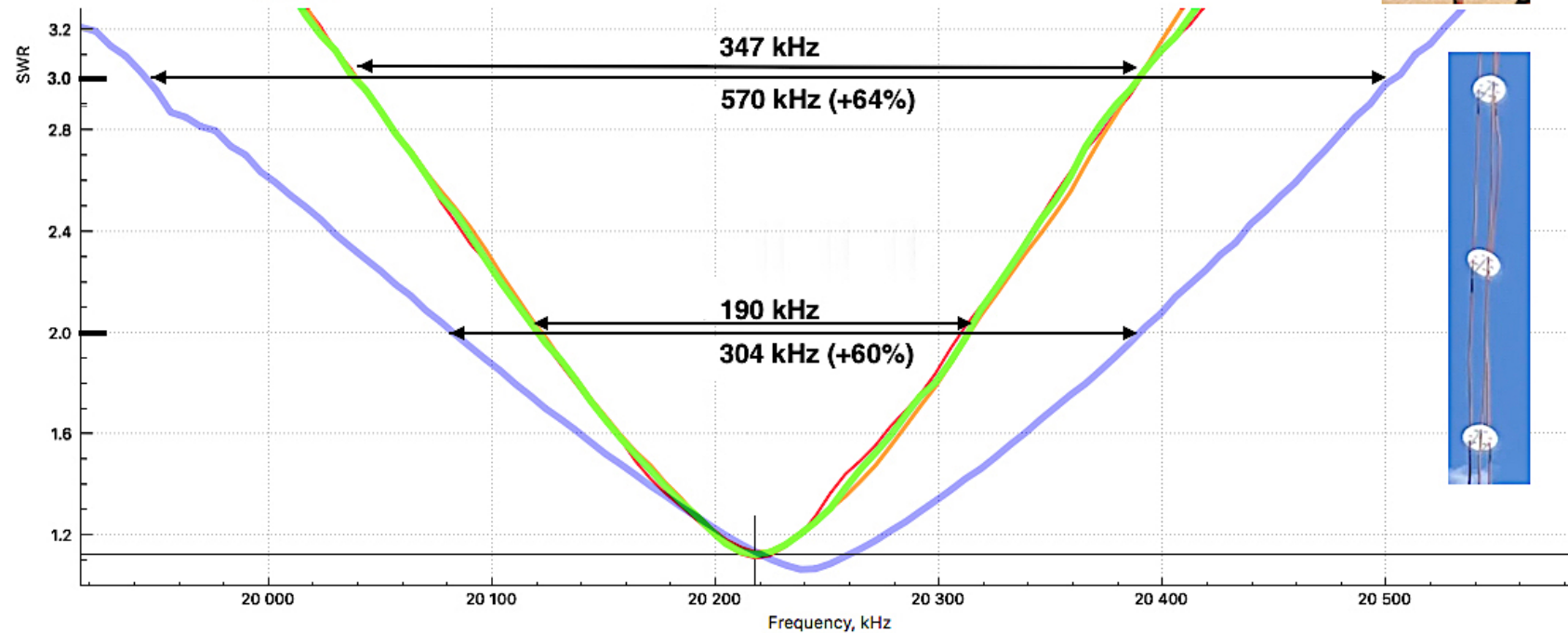
45 mm Polypropylene Load Spreading Washers every 14" on down wires.

Caging wire-to-wire separation  
1-1/16" or 27mm

Small holes fit snugly on 12-gauge hardware store THHN wire.



Spiral Cable Wrap  
(bunched tightly)



ERP (Effective Radiating Power or 'antenna efficiency') vs SWR: 1.0 = 100% 1.2 = ~99% 1.6 = ~95% 2.0 = ~90% 2.4 = ~83% 3.0 = ~75%

## (9b) Caging 'Shift':

A reflective yagi element is typically 5% *larger* than the driven element (although I have seen instances as low as 3.5% for a cubic quad), so it is 5% *lower in frequency*. For SSB, 21,300 kHz is a good center frequency for the driven element, so  $0.95 \times 21,300 = 20,235$  kHz is the reflector element's target **center frequency** – **the frequency where the SWR minima occurs**. Today's tuning (violet line above) hit 20,240 kHz at an SWR 1.05, easily good enough for my upcoming yagi reflector experiment.

I also discovered (again) that caging an antenna shifts the center frequency *significantly lower* (leftward), which means that since the frequency has decreased – the antenna loop has effectively become 'larger'.

This minima shift was beyond the tuning slider travel that I had remaining, required shortening the 'down wires' by about 5" to compensate. This kind of adjustment – shortening or lengthening the 'down wires' near the pigtails – is fairly easy for a Hen-Delta to accommodate, but I have also learned to build longer tuning stubs in the first place to avoid the inconvenience.

This graph (right) shows the 15m **reflector element** when first transitioning from the minimal caging provided by spiral cable wrap (inset in graph on previous page) to the better (but still small) 1.1" cage provided by the poly- propylene washers. After any caging modification the antenna must be retuned.

I had yet to consider exploring still larger caging rings, but that time was coming soon.



# (10) Two-element (Driven & Reflector) Hen-Delta-Yagi experiment:

2023-0712: To the best of my knowledge a Hen-Delta-*Yagi* configuration has never been built and tested before. The appeal of a Hen-Delta-Yagi is that it has a very small 2D footprint (the 2-element version is 6.5-feet wide on a 10-foot boom) and has a correspondingly short turning radius – provided that you have the vertical space under a tree, mast, or tower. The 15m Hen-Delta is about 22.5-feet tall. At my location a standard yagi would be impossible, so I was hopeful that a Hen-Delta-Yagi was achievable.

For the test I obtained the kind assistance of my radio club. We coordinated by cell phone and they transmitted a continuous 5-watt CW tone on an agreed upon frequency for a period of a few minutes while we *manually* rotated the Driven Element and the Reflector Element about 3/4 of a turn and back again – our mechanical limit under the circumstances. The rotational angle of the boom as shown on my upward looking ‘RV Backup Monitor’ and the signal strength in S-units were simultaneously recorded on a video camera for later analysis, as shown in the inset collage on the next page, at lower left.

The results were what I was hoping to see from a simple 2-element yagi, about +3 dB of gain in the forward direction and about -3 dB in the rearward direction. There were gentle nulls to the sides. The black dots represent actual data points. To fill in the missing quadrant of data for better visualization, a duplicate **mirrored** data set was added (red dots). The native resolution of the IC-7300 is 0.2 S-units, but correcting for the meter’s non-linearity (table and link at right – one of many radios in the table; used with permission) allows measurement resolution that is actually near 0.1 S-units (1 S-unit being 6 dB). Element separation was 10-feet or 0.214 wavelengths. In studying yagis I have seen element separations of 0.12 to 0.40 wavelengths, so 0.214 should be in the general ballpark.

Note that this test was a *relative-to-self* performance test, not an *absolute* performance test. To be truly valid a horizontal dipole would be needed to simultaneously record its signal strength.... or a second test with a dipole could have been performed shortly after the first one. But at my location the tree itself would be within the turning radius of a dipole – the entire reason for my interest in the Hen-Delta in the first place.

Weeks later...

A three-element 15m Hen-Delta with a reflector and a director was built and tested similarly. Curiously, it produced a small amount of gain in the *wrong direction* – in the reflector’s general direction but also off to one side by about 30°. I have read that similar results can occur with other yagis (cubic quads) if they receive a signal at the *reflector’s* tuned frequency, but that wasn’t the case here. I am considering building a more manageable scale model 2m Hen-Delta model that can be more easily varied dimensionally and also compared in real time to a 2m dipole – but I don’t have the equipment to receive an accurate, high resolution signal strength, let alone *two* such signal strengths (Hen-Delta and dipole). So I am at a standstill for the time being.

**For the present, a functional two-element Hen-Delta Yagi can be thought of as *likely achievable*. But without optimized dimensions based on computer simulations or RF lab testing, it must remain ‘unproven’.**

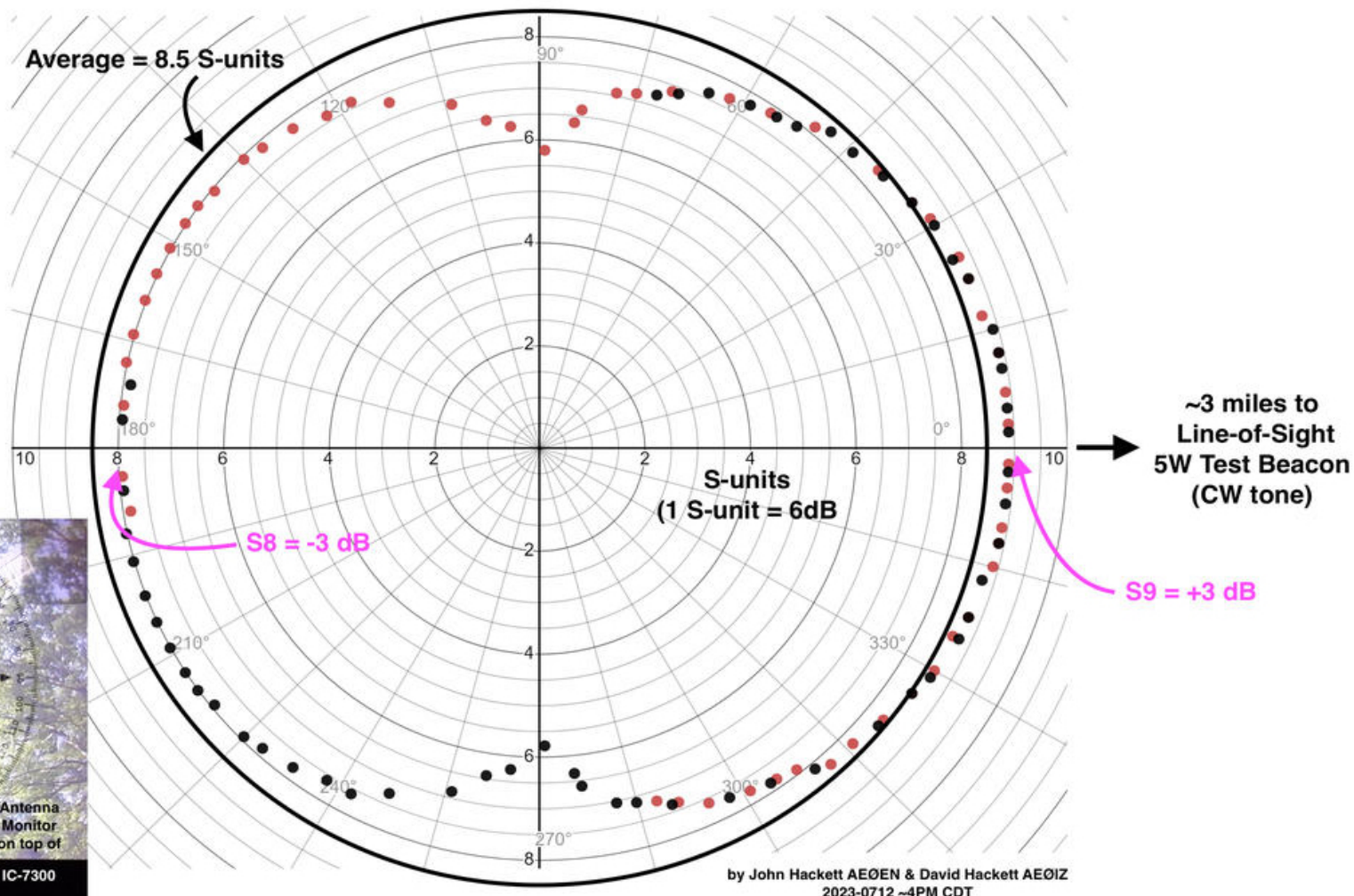
| S-Meter Calibration Test Summary of popular HF transceivers   |    |    |    |    |    |      |      |      |      |     |     |     |
|---|----|----|----|----|----|------|------|------|------|-----|-----|-----|
| Conducted on laboratory test bench using R&S SMA100A Signal Generator, HP/Agilent Coax Attenuator HP8491A & HP11708A and Tektronix VNA (s9=50uV=-73dBm, s1=0.2uV=-121dBm • -6dB/S-unit) |    |    |    |    |    |      |      |      |      |     |     |     |
| Measurements conducted @ 25 degC ambient after 60 mins warmup   |    |    |    |    |    |      |      |      |      |     |     |     |
| IARU Standard   | S1 | S2 | S3 | S4 | S5 | S6   | S7   | S8   | S9   | +20 | +40 | +60 |
| IC-7300   | x  | x  | x  | x  | S1 | S2.8 | S5.1 | S7.6 | S9+1 | +19 | +38 | +54 |

For S-meter calibrations of other radios see:

<https://vu2nsb.com/radio-systems/amateur-radio-station-ham-shack/radio-transceiver-s-meter/>

# Two-element (Driven & Reflector) Hen-Delta-Yagi Radiation Pattern

Corrected for IC-7300 S-meter Non-Linearity



Antenna was turned manually with ropes so data covers only 270°, mirror-image data was used to fill in the pattern

Test frequency 21,210 kHz on 15m band,  
Reflector element tuned to -5% driven element's minima frequency,  
element separation 0.214 wavelengths (10-feet).

S-unit data

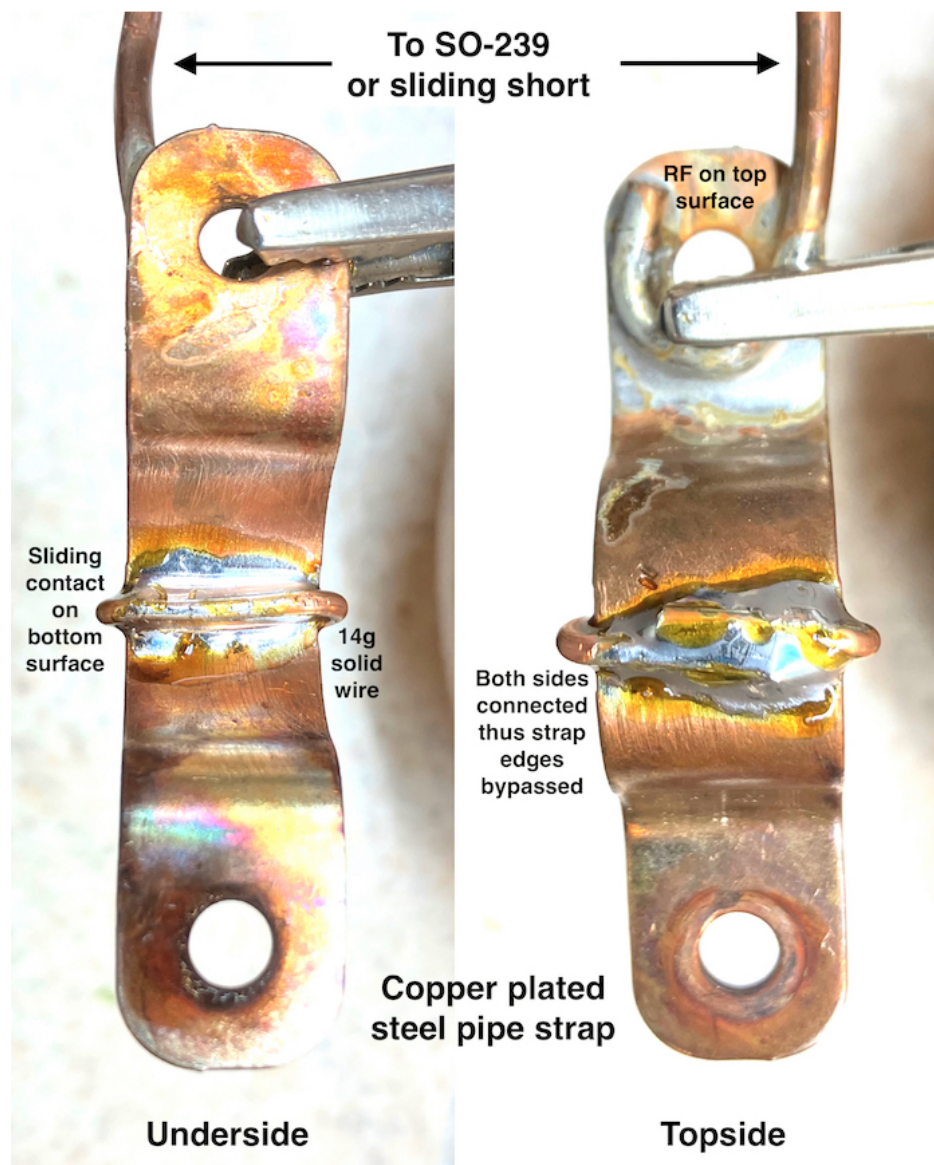
## (11) Misc. Details and Construction Notes (early version):

**Sliding contacts v1.2 (see photo at right):** Using copper pipe for the tuning stub works very well and is reasonably priced. The common hardware store copper-plated steel pipe straps need to have the holes enlarged for #10 bolts and the outer strap edges are often nicked. Any unplated surface will slowly rust. I wasn't keen on the RF having to wrap around the thin edge of the strap, or travel through the steel, so I added this 14g wire to connect the underside (which makes sliding contact with the copper pipe) to the topside (which carries the RF to the tuning stub). This modification may be functionally unnecessary but it is difficult to know for certain, and I would rather error on the side of conservative design. It does keep some of the cosmetic rust stain/powder off of the copper pipe and allows the sliders to move up and down more easily. The single sliding contact point cleans/scratches the copper pipe with each adjustment.

**Note 1:** Since I only run 100W as this is written, I don't know how much RF power these moveable tuning contacts can handle when clamped tight to the copper pipe? When the knurled nuts are tightened these contacts are under so much pressure they cannot be moved by hand, and that's certainly a better connection than high power relay contacts or any coax A/B switch.

**Update to Note 1:** These sliding contacts were later upgraded to **v2.0** (see Chapter 17 below) and easily handle 800W from my SB-1000 amplifier. I have no doubt they would carry 1500W effortlessly.

**Note 2:** I suggest NIBCO 624 copper-plated steel straps. The cheap straps with ridges are very thin and have taken over many hardware stores.



**Note 2:** (Updated) I discovered that standard crimp loop connectors simply are not strong enough for long term use. This isn't too surprising since they are tin-lead coated *copper*. The connector at right broke and forced me to consider much stronger options. After some research I decided upon the two-hole, 8-gauge 'lugs' shown at lower right. These have several specifications: wire gauge range, hole diameter, and hole separation distance (center to center). Choose the lug that meets your present and anticipated future needs, especially with respect to accepting multiple wires of whatever gauge you are using. Mine have 1/4" holes with 5/8" separation, so any gauge future lug with that hole pattern will be compatible... Another advantage of using two-hole lugs is that you do not need to add 'jam nuts' to secure the stainless steel bolts, since having two bolts prevents the connection from rotating and trying to loosen the nuts from the bolts. Lock washers are sufficient.

Note 3: (obsolete, omitted)

**Note 4:** (Updated) One of my first wire-to-cap butt-joint soldering connections almost tore free. I now drill *through* the caps (and pipe) of the top copper pipe element (and also the tuning stub caps), wrap 8-gauge solid copper wire through and around it, and butane-solder it together. It is vastly stronger.

**Note 5:** It is a very good idea to drill *two* 1/16" 'weep holes' in the top copper pipe (one near each end, on the bottom side) and at the bottom of the tuning stub (one near each elbow) to allow any condensation to escape. It also vents internal air pressure during pipe heating and soldering, which can otherwise push assembled parts apart. I suggest using a center punch to make a dimple in the copper for the bit to start in, and watch the bit carefully as it tends to wander laterally on and through the soft copper.

**Note 6:** While constructing a 15m, 3-element Hen-Delta-Yagi for testing (previously described) I found that I needed a larger tuning stub than 24" and built one 40" (1m) tall. I later created one 5' tall. All of these tune nicely as single- or dual-band antennas, or to tune reflector or director elements. One of the *joys* of the Hen-Delta design is that the tuning stub makes tuning so easy and versatile. It's not *effortless*, of course, as it takes a dozen or more iterations to home in on the desired frequency and SWR minima. By the way, tuning locally **at** the antenna doesn't produce exactly the same result as tuning in the shack due to the coax run, so once you get the tuning close to where you want it, move the RigExpert to the shack and connect it to your computer via USB. The companion AntScope software is good quality and allows large multi-trace graphs to be made and saved (as seen elsewhere in this document). The software completely controls the RigExpert over my 10' USB cable.

Be aware that my RigExpert AA230 Zoom will randomly 'lock up' once every 2-8 hours of 'on' time. I just remove and reinsert one AAA battery to reboot it, or leave one battery out and unplug the USB connection briefly. This will sometimes also freeze the AntScope software, so it will have to be closed and relaunched. So be sure to SAVE each run (trace) that is important to you. I have emailed RigExpert tech support about the inconvenience of this problem and suggested that the AntScope software be updated to do a SAVE ALL feature after *every* run, then do a LOAD ALL when the program is launched. That would make any crash insignificant). This occasional 'locking up' is a minor nuisance that I can overlook since the RigExpert is such a fine instrument.



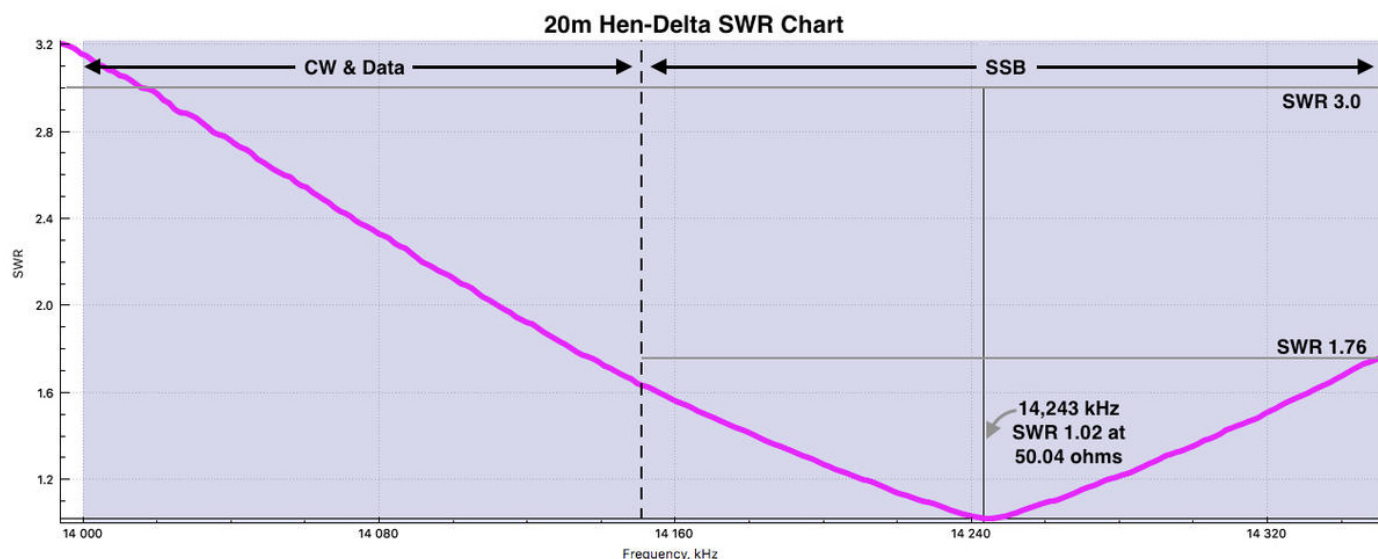
## (12) The 20m Hen-Delta:

2023-1016: Since the 15m Hen-Delta-Yagi was too large and heavy to experiment with easily, I decided to re-purpose its director and reflector and combine their parts to make a 20m Hen-Delta (right). The 20m band here in St. Louis, Missouri is *very* noisy (ghastly) with my loop antennas, and I hoped that the Hen-Delta's quiet nature might make the band more usable. It helps considerably, as you will see on the screen captures below, but the band is still pretty bad.

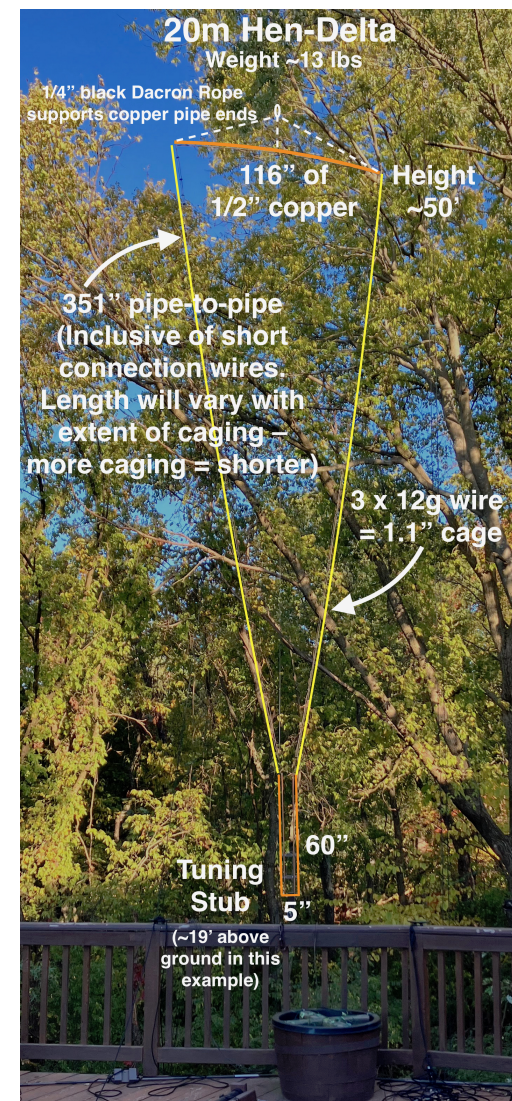
The 1.1" caging kept the SWR under 1.76 across the entire SSB portion of the band. If I were going to rebuild this antenna today I would use 6" ABS rings for a much wider bandwidth, but I hadn't progressed that far in my caging research when this was built – almost a year ago. The construction effort is almost the same irrespective of the cage diameter.

At a height of ~50' above ground (~0.7 wavelengths) the tuning stub is still ~19' above ground. This antenna was used a few times but the band was so noisy – except for two small quiet regions – that I kept the 15m Hen-Delta at this location. I ended up borrowing the 60" tuning stub for the 10m/12m dual-band project and bringing in the remainder of the 20m antenna for storage or repurposing.

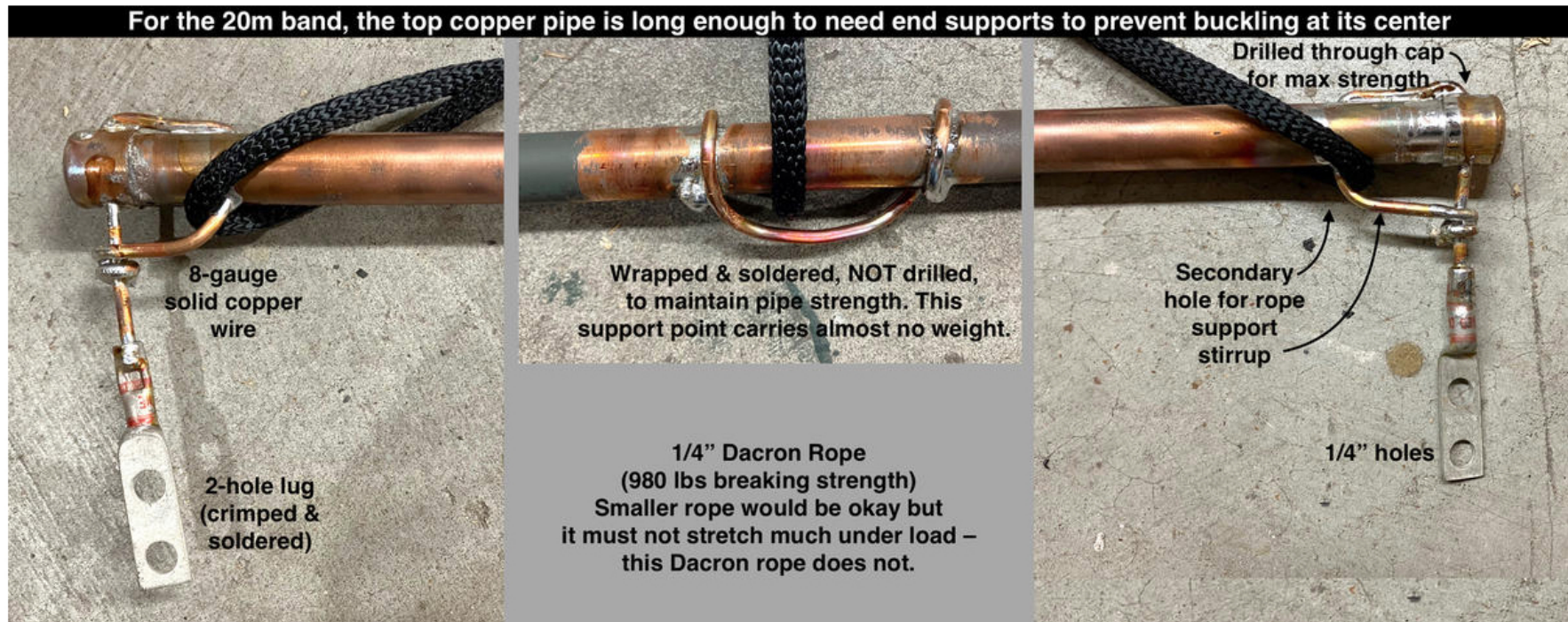
With a 1.1" cage the SWR curve is 'adequate' as shown here:



ERP (Effective Radiating Power or 'antenna efficiency') vs SWR: 1.0 = 100% 1.2 = ~99% 1.6 = ~95% 2.0 = ~90% 2.4 = ~83% 3.0 = ~75%



For the 20m band the top element is long enough – a bit more than 9.5 feet – to **require** support at the ends rather than from the center, else it might buckle (collapse) at the center. **This photo illustrates several new improvements**, including **two-hole lugs**, the **8-gauge solid copper ‘pigtailed’** at the ends (also on the upper ends of the 60-inch tuning stub), and adding **stirrups** with the copper wire rather than using nylon padeyes for the rope constraints. Note that the center support point is a safety line and normally carries no weight.



## 20m Band Noise in the City:

I have no idea why the 20m band is so noisy at my location here in the suburbs, but I have heard other amateurs on the air complain that 20m was noisy for them as well. I was listening to an amateur in Africa who stated that, “whenever he pointed his 20m antenna at North America, all he heard was noise”. Curiously, there are two, small, relatively quiet spots in the band, at  $\sim 14.210 \pm 10\text{kHz}$  (shown below) and at  $\sim 14.300 \pm 10\text{kHz}$ . Those narrow regions are always quiet, and what you see below is typical. Compare the ‘A’ and ‘B’ noise levels (and the boxes and ovals) on both screens and note how much *quieter* the Hen-Delta antenna is (left) compared to the 80m Horizontal Loop antenna (right) – about 10dB quieter across the entire spectrum. The white SSB signals ‘1’ and ‘2’ (right side of each screen) are each  $\sim 6\text{dB}$  stronger with the Hen-

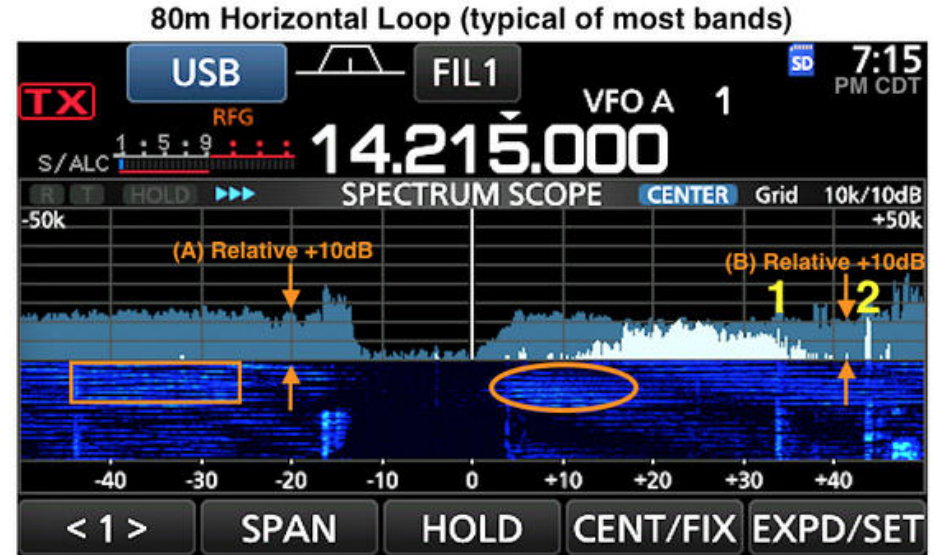
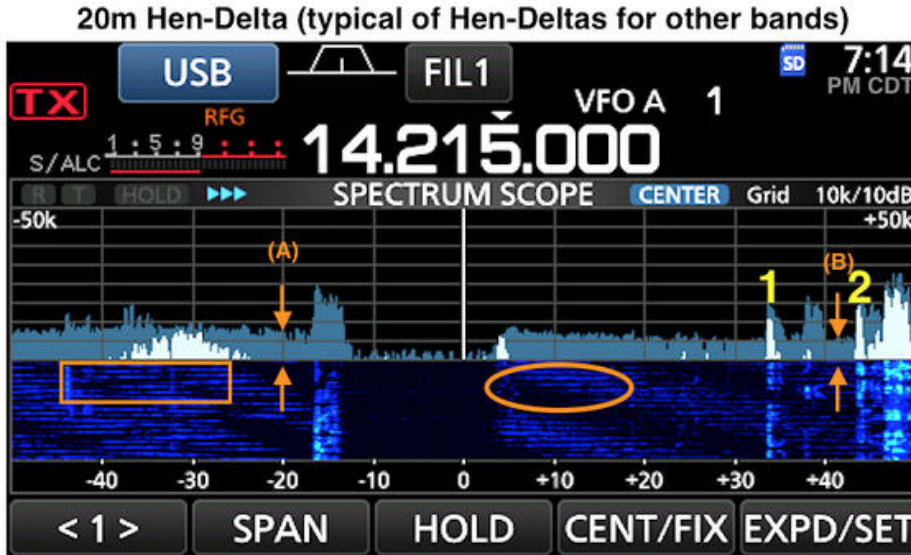
Delta (I watched these two signals for some time and the screen captures *are* representative of relative signal strength). That makes the *signal-to-noise* ratio  $\sim 16\text{dB}$  stronger for the Hen-Delta. The 20m Hen-Delta was at about 50’ or 0.7 wavelengths above ground.

These two screen captures were taken about **4 seconds apart** by switching the tuner from Coax-1 (80m loop) to Coax-2 (Hen-Delta). The Hen-Delta was tuned perfectly and the loop had very similar C & L tuner settings, thus the two signal spectrums are comparable.

(2025-0525: Noise on 20m has dropped significantly since early May.)

### 20m Band Noise in Fenton, Missouri (St. Louis Suburbs) on October 15, 2023 A Comparison of Hen-Delta vs Horizontal Loop Antennas

(Only the Palstar tuner’s antenna selector switch was changed since the tuning parameters of the two antennas were very similar. Screen captures were 4 seconds apart.)



Hen-Delta signal reception (yellow numbers) is typically a few dB better than the horizontal loop in my experience.  
This makes the signal-to-noise ratio much better for the Hen-Delta.

## (13) **Hen-Delta Stealthiness:**

2023-0930 (Updated on 2024-0827): No tower and no mast. Can you see the two (stealthy) caged Hen-Delta antennas against the trees in these morning and afternoon photos? A little ultra-flat dark brown spray paint helps a lot!



Here they are:

15m at 55' in background, 10m at 40' in foreground:



# (14) 10m HEN-DELTA WITH A 6-WIRE, 3.5" CAGE:

2023-1108: Okay, *now the caging is starting to get serious* – about 1% of wavelength! For cost savings the original two 12-gauge wires (per side) were reused since they were already about the correct length, with four additional 14-gauge wires (per side) added to create a 6-wire cage. When tuned, **caging shortened the ‘down wires’ by 21” relative to their original length**. The cage’s 6 parallel wires have a wire resistance equal to about one 8-gauge wire (per side).

As an experiment in maximum caging, the single upper copper pipe element was increased to three 1/2” pipes (see the inset photo at upper left in the collage at right). As it turns out – and to my surprise – this produced very little additional broadband effect (see two pages below) since the caged down wires are so effective.

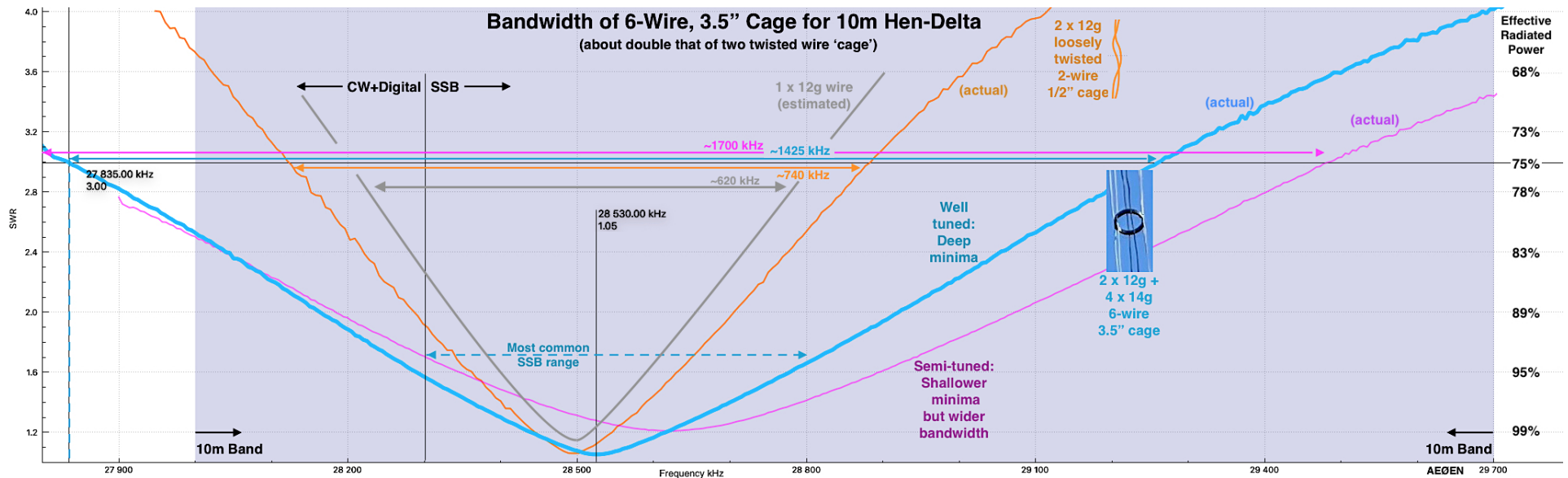
Note the now-*caged* antenna against the background of leafless trees in winter remains fairly stealthy from a distance. It is even more so in summer against a complex foliage-and-shade forest pattern. The wires and rings were spray painted an ultra-flat dark brown.



### 10m Hen-Delta RigExpert AntScope Chart:

The **thick blue trace** is the final result of caging both the top pipes and 'down wire' elements to the equivalent of about 2" diameter conductors. The orange trace was the original 2-loosely-twisted wire 'cage' (barely a cage at all) which was only 16% wider than a single 12-gauge wire (gray trace)). **Important: The magenta trace shows a 'semi-tuned' but even broader (lower Q) effect which is very interesting – by giving up a couple percent of ERP at the**

**SWR minima at the center (see the ERP table embedded at right) you can widen the entire curve substantially. This may be very useful if you prefer to operate in the widest portion of the band possible.** And remember, this is a 3.5" (0.9% of bandwidth) cage, not a 6" (1.5% of bandwidth) or 8" (2% of bandwidth) cage... although 1% does buy you about 80% of the maximum improvement due to a diminishing returns effect.



(Zoom in to see detail.)

**Note that if a 6" cage diameter (1.5% of wavelength) had been utilized rather than 3.5" (~1% of wavelength) the blue line above would have been about only 10%-15% wider. Due to a 'diminishing returns' effect, the maximum bandwidth improvement that caging provides occurs at a cage diameter of ~2% of wavelength.**

## Experiment: Is a triple-pipe ('caged') top element really much *better* than a single-pipe top element? Surprisingly, the answer is: *Not by much!*

2023-1122: I swapped out the triple-pipe top element shown (right) for a single copper pipe. The resulting SWR curve shift is shown on the next page. The shift was in an unexpected direction... but it is what it is. After retuning by moving the feedpoint slider all the way to the top and also shortening the pig-tails on the top single pipe element, the curve shifted to that shown on the right graph (orange curve). That is the maximum shift that I can manage without trimming two perfectly good 6-wire caged down runs (which is why I now prefer tuning stubs longer than 24"), so I decided to *graphically* clone and shift the orange curve in order to nest it within the magenta triple-pipe curve for a direct comparison (the blue curve, below right). As you can see, the bandwidth with the top element a **triple-pipe (magenta curve)** is barely wider than a **single pipe (blue curve)**, and not enough better to justify the extra construction effort, cost, and weight of two more copper pipes – you would be better off using a larger 6" or 8" cage for the down wires with very little additional effort or cost caused by the large spreader rings! This is unexpected and interesting, strongly suggesting that *the broad-banding effect of caging is dominated by the fraction of the antenna which is caged, and that caging 'bottlenecks' (omissions) in the antenna have little effect*. The broad-banding may or may not be a linear function of the fraction of the antenna caged – I don't know if this has ever even been studied (see Chapter 16 below) since most antennas are either uncaged or fully caged. In this case, the caging diameter of the top element was *decreased* from about an effective 2" to an actual 5/8" (triple pipe to one pipe) for about 12% of the antenna's perimeter and the effect on bandwidth was nearly negligible. Fascinating!

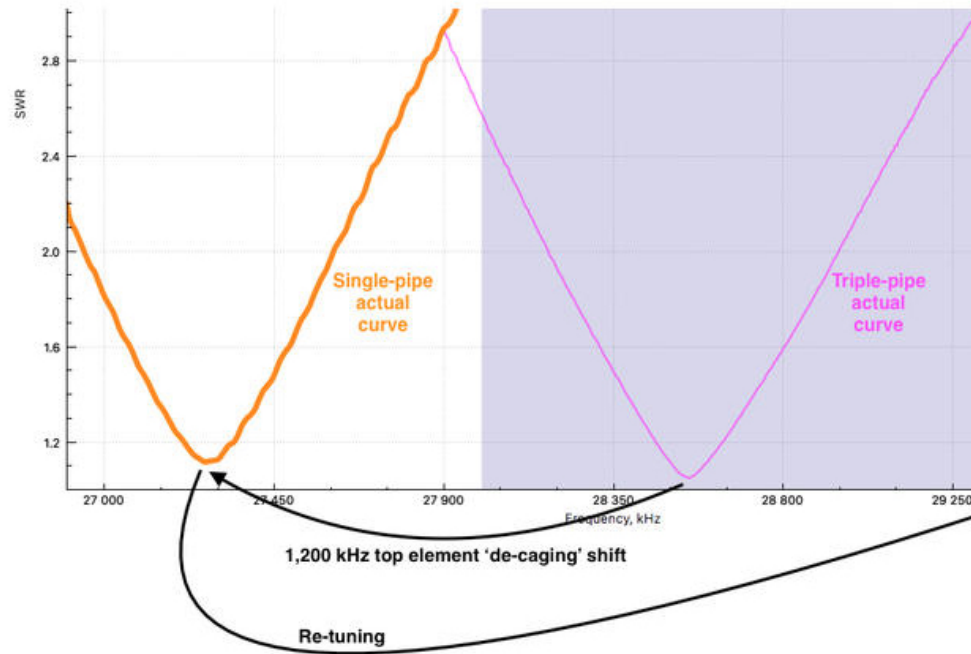
Thus for Hen-Delta designs, use a single copper pipe at the top and then cage the down wire runs as much as you think practical – especially true for the 10m band due to it being a very wide band. Other bands, being narrower, benefit from caging but to a lesser degree – since the bandwidth become far wider than the band itself – although that insures a very low SWR across the entire band

which may still be worthwhile. For 10m, my fully caged Hen-Delta (as shown at the top of this chapter) is so broadband that I can set my Palstar tuner to midrange tuning-table C and L values and not really need to adjust them again over the first 500 kHz of the SSB band. That's where 95% of SSB activity occurs, partly because everyone who can do so uses a yagi and they are relatively narrowband.

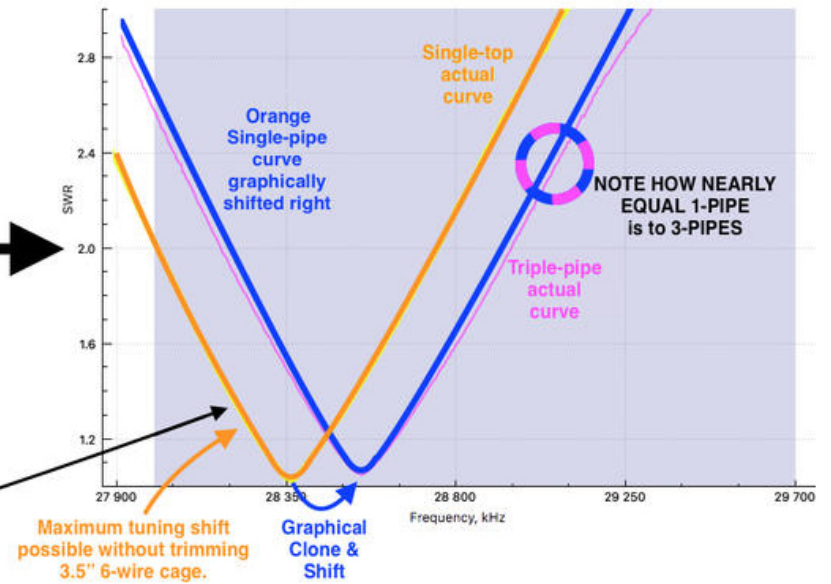


By the way, **once you undertake to cage an antenna, the additional effort and cost to add one or two wires is minimal (so use six), and the additional effort of using larger spreader ring diameters (say 6" vs 3.5") is almost zero**. Consider the small graph at the top of Chapter 15 (next chapter) and notice how increasing the wire count (at a given diameter) gains you a little, but increasing spreader ring diameter gains the most per unit of effort expended. For a wide band such as 10m consider going as large as is practical – 6" or 8" – with six wires. I am nevertheless quite pleased with my 3.5" 6-wire cage. Note that I have read but a single anecdotal comment that the maximum useful cage diameter is 2% of the antenna's wavelength, but my experiences suggest that this is true. My 3.5" cage is slightly less than 1% of wavelength, which provides about 80% of the bandwidth improvement that 2% would provide, due to a diminishing returns effect. All SWR charts made with RigExpert's AntScope 2.2 connected to my RigExpert AA230-Zoom

## One 1/2" Copper Pipe Replaces Triple-Pipe



## Re-tuned and Overlayed on Triple-Pipe Curve



ERP (Effective Radiating Power or 'antenna efficiency') vs SWR: 1.0 = 100% 1.2 = ~99% 1.6 = ~95% 2.0 = ~90% 2.4 = ~83% 3.0 = ~75%

All SWR charts made with RigExpert's AntScope 2.2 connected to my RigExpert AA230-Zoom

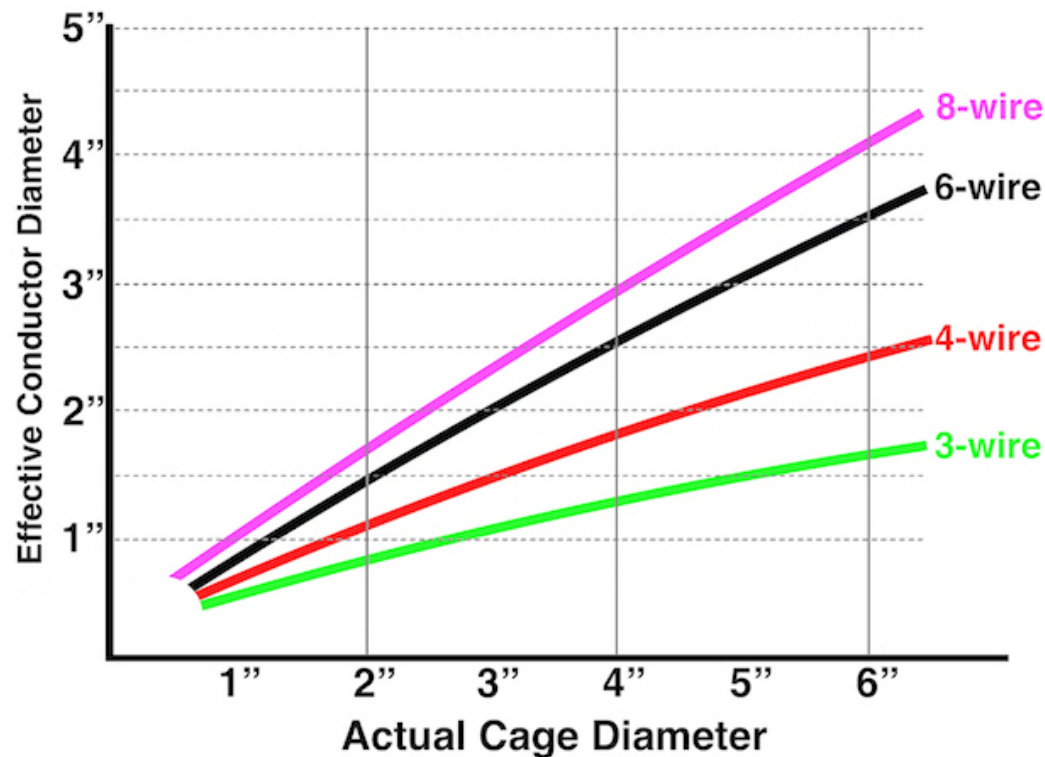
## (15) CAGE DIAMETER VS EFFECTIVE CONDUCTOR GRAPH & TABLE:

2023-1109: Note that the difference between *stranded* wire and *solid* wire cages is small enough to ignore. Also note that nominal 1/2" copper pipe has an actual outside diameter of 5/8", and nominal 3/4" copper pipe has an actual outside diameter of 7/8".

This simplified graph shows the relationship between the *actual* cage diameter and the *effective* conductor diameter. In the example above (Chapter 14) a 3.5", 6-wire cage is equivalent to a conductor of ~2.25" diameter. A 6", 6-wire

cage is equivalent to a conductor of 3.5" diameter. As you can see, a cage of 6 wires vs 4- or 8-wires is a good cost-weight vs performance point. Eight wires is 1/3rd more wire weight and wire cost to build for little extra gain. The following page shows a spreadsheet illustration that I created to explore caging options. For example, consider a 6" cage of six 14-gauge wires. From the 6-wire, 14-gauge **row** and 6" **column** read that the effective conductor diameter is 87mm (3.5"), or 58% of the 6" cage diameter.

Cage Diameter vs Effective Conductor Diameter



If curious about the *effective AWG gauge* of multiple small wires try these calculators: [https://www.wirebarn.com/Combined-Wire-Gauge-Calculator\\_ep\\_42.html](https://www.wirebarn.com/Combined-Wire-Gauge-Calculator_ep_42.html)  
As examples: Six 14-gauge wires are equal to one 6-gauge wire in terms of **wire resistance**. Six 12-gauge wires are equal to one 4-gauge wire.

## ACTUAL CAGE DIAMETERS vs EFFECTIVE CONDUCTOR DIAMETER for STRANDED WIRE GAUGES

| STRANDED Wire Gauge # | STRANDED Wire Diameter (mm) | STRANDED Wire Diameter (m) | Number of Cage wires (n) | ~0.5" Cage         |       | ~1" Cage           |       | ~2" Cage           |       | ~3" Cage           |       | ~4" Cage           |       | ~5" Cage           |       | ~6" Cage           |       | ~12" Cage          |       |
|-----------------------|-----------------------------|----------------------------|--------------------------|--------------------|-------|--------------------|-------|--------------------|-------|--------------------|-------|--------------------|-------|--------------------|-------|--------------------|-------|--------------------|-------|
|                       |                             |                            |                          | Diameter (mm)      | 100%  | Diameter (mm)      | 100%  | Diameter (mm)      | 100%  | Diameter (mm)      | 100%  | Diameter (mm)      | 100%  | Diameter (mm)      | 100%  | Diameter (mm)      | 100%  | Diameter (mm)      | 100%  |
|                       |                             |                            |                          | Effective Diameter | Eff % | Effective Diameter | Eff % | Effective Diameter | Eff % | Effective Diameter | Eff % | Effective Diameter | Eff % | Effective Diameter | Eff % | Effective Diameter | Eff % | Effective Diameter | Eff % |
| 12                    | 2.36                        | 0.00236                    | 8 wires                  | 12mm               | 97%   | 22mm               | 89%   | 41mm               | 81%   | 58mm               | 77%   | 74mm               | 74%   | 91mm               | 72%   | 106mm              | 71%   | 195mm              | 65%   |
| 14                    | 1.85                        | 0.00185                    |                          | 11mm               | 94%   | 21mm               | 86%   | 39mm               | 79%   | 56mm               | 75%   | 72mm               | 72%   | 88mm               | 70%   | 103mm              | 69%   | 189mm              | 63%   |
| 16                    | 1.47                        | 0.00147                    |                          | 11mm               | 91%   | 21mm               | 83%   | 38mm               | 77%   | 55mm               | 73%   | 70mm               | 70%   | 85mm               | 68%   | 100mm              | 67%   | 184mm              | 61%   |
| 18                    | 1.24                        | 0.00124                    |                          | 11mm               | 90%   | 20mm               | 82%   | 37mm               | 75%   | 53mm               | 71%   | 69mm               | 69%   | 84mm               | 67%   | 98mm               | 65%   | 180mm              | 60%   |
| 20                    | 0.94                        | 0.00094                    |                          | 10mm               | 86%   | 20mm               | 79%   | 36mm               | 72%   | 52mm               | 69%   | 66mm               | 66%   | 81mm               | 65%   | 95mm               | 63%   | 174mm              | 58%   |
| 22                    | 0.762                       | 0.000762                   |                          | 10mm               | 84%   | 19mm               | 77%   | 35mm               | 70%   | 50mm               | 67%   | 65mm               | 65%   | 79mm               | 63%   | 92mm               | 61%   | 169mm              | 56%   |
| 12                    | 2.36                        | 0.00236                    | 6 wires                  | 11mm               | 92%   | 20mm               | 81%   | 36mm               | 72%   | 51mm               | 67%   | 64mm               | 64%   | 77mm               | 62%   | 90mm               | 60%   | 161mm              | 54%   |
| 14                    | 1.85                        | 0.00185                    |                          | 11mm               | 88%   | 19mm               | 78%   | 35mm               | 69%   | 49mm               | 65%   | 62mm               | 62%   | 74mm               | 60%   | 87mm               | 58%   | 154mm              | 51%   |
| 16                    | 1.47                        | 0.00147                    |                          | 10mm               | 85%   | 19mm               | 75%   | 33mm               | 67%   | 47mm               | 62%   | 59mm               | 59%   | 72mm               | 57%   | 83mm               | 56%   | 148mm              | 49%   |
| 18                    | 1.24                        | 0.00124                    |                          | 10mm               | 82%   | 18mm               | 73%   | 32mm               | 65%   | 45mm               | 61%   | 58mm               | 58%   | 70mm               | 56%   | 81mm               | 54%   | 144mm              | 48%   |
| 20                    | 0.94                        | 0.00094                    |                          | 9mm                | 79%   | 17mm               | 70%   | 31mm               | 62%   | 43mm               | 58%   | 55mm               | 55%   | 66mm               | 53%   | 77mm               | 52%   | 138mm              | 46%   |
| 22                    | 0.762                       | 0.000762                   |                          | 9mm                | 76%   | 17mm               | 67%   | 30mm               | 60%   | 42mm               | 56%   | 53mm               | 53%   | 64mm               | 51%   | 75mm               | 50%   | 133mm              | 44%   |
| 12                    | 2.36                        | 0.00236                    | 4 wires                  | 10mm               | 79%   | 16mm               | 66%   | 28mm               | 55%   | 38mm               | 50%   | 47mm               | 47%   | 55mm               | 44%   | 63mm               | 42%   | 106mm              | 35%   |
| 14                    | 1.85                        | 0.00185                    |                          | 9mm                | 75%   | 16mm               | 62%   | 26mm               | 52%   | 35mm               | 47%   | 44mm               | 44%   | 52mm               | 41%   | 59mm               | 40%   | 100mm              | 33%   |
| 16                    | 1.47                        | 0.00147                    |                          | 8mm                | 70%   | 15mm               | 59%   | 25mm               | 49%   | 33mm               | 44%   | 41mm               | 41%   | 49mm               | 39%   | 56mm               | 37%   | 94mm               | 31%   |
| 18                    | 1.24                        | 0.00124                    |                          | 8mm                | 67%   | 14mm               | 56%   | 24mm               | 47%   | 32mm               | 43%   | 40mm               | 40%   | 47mm               | 38%   | 54mm               | 36%   | 90mm               | 30%   |
| 20                    | 0.94                        | 0.00094                    |                          | 8mm                | 63%   | 13mm               | 52%   | 22mm               | 44%   | 30mm               | 40%   | 37mm               | 37%   | 44mm               | 35%   | 50mm               | 33%   | 84mm               | 28%   |
| 22                    | 0.762                       | 0.000762                   |                          | 7mm                | 60%   | 12mm               | 50%   | 21mm               | 42%   | 28mm               | 38%   | 35mm               | 35%   | 42mm               | 33%   | 48mm               | 32%   | 80mm               | 27%   |
| 12                    | 2.36                        | 0.00236                    | 3 wires                  | 8mm                | 67%   | 13mm               | 52%   | 21mm               | 41%   | 27mm               | 36%   | 33mm               | 33%   | 38mm               | 30%   | 43mm               | 29%   | 68mm               | 23%   |
| 14                    | 1.85                        | 0.00185                    |                          | 7mm                | 61%   | 12mm               | 48%   | 19mm               | 38%   | 25mm               | 33%   | 30mm               | 30%   | 35mm               | 28%   | 40mm               | 26%   | 63mm               | 21%   |
| 16                    | 1.47                        | 0.00147                    |                          | 7mm                | 57%   | 11mm               | 45%   | 18mm               | 35%   | 23mm               | 31%   | 28mm               | 28%   | 33mm               | 26%   | 37mm               | 24%   | 58mm               | 19%   |
| 18                    | 1.24                        | 0.00124                    |                          | 6mm                | 54%   | 11mm               | 42%   | 17mm               | 33%   | 22mm               | 29%   | 26mm               | 26%   | 31mm               | 25%   | 35mm               | 23%   | 55mm               | 18%   |
| 20                    | 0.94                        | 0.00094                    |                          | 6mm                | 49%   | 10mm               | 38%   | 15mm               | 30%   | 20mm               | 27%   | 24mm               | 24%   | 28mm               | 22%   | 32mm               | 21%   | 50mm               | 17%   |
| 22                    | 0.762                       | 0.000762                   |                          | 5mm                | 46%   | 9mm                | 36%   | 14mm               | 28%   | 19mm               | 25%   | 23mm               | 23%   | 26mm               | 21%   | 30mm               | 20%   | 47mm               | 16%   |
| 12                    | 2.36                        | 0.00236                    | 2 wires                  | 5mm                | 44%   | 8mm                | 31%   | 11mm               | 22%   | 13mm               | 18%   | 15mm               | 15%   | 17mm               | 14%   | 19mm               | 13%   | 27mm               | 9%    |
| 14                    | 1.85                        | 0.00185                    |                          | 5mm                | 39%   | 7mm                | 27%   | 10mm               | 19%   | 12mm               | 16%   | 14mm               | 14%   | 15mm               | 12%   | 17mm               | 11%   | 24mm               | 8%    |
| 16                    | 1.47                        | 0.00147                    |                          | 4mm                | 35%   | 6mm                | 24%   | 9mm                | 17%   | 11mm               | 14%   | 12mm               | 12%   | 14mm               | 11%   | 15mm               | 10%   | 21mm               | 7%    |
| 18                    | 1.24                        | 0.00124                    |                          | 4mm                | 32%   | 6mm                | 22%   | 8mm                | 16%   | 10mm               | 13%   | 11mm               | 11%   | 12mm               | 10%   | 14mm               | 9%    | 19mm               | 6%    |
| 20                    | 0.94                        | 0.00094                    |                          | 3mm                | 28%   | 5mm                | 19%   | 7mm                | 14%   | 8mm                | 11%   | 10mm               | 10%   | 11mm               | 9%    | 12mm               | 8%    | 17mm               | 6%    |
| 22                    | 0.762                       | 0.000762                   |                          | 3mm                | 25%   | 4mm                | 17%   | 6mm                | 12%   | 8mm                | 10%   | 9mm                | 9%    | 10mm               | 8%    | 11mm               | 7%    | 15mm               | 5%    |

The effective radius of a multi-wire cage is given by:

$$\text{EffectiveRadius} = \text{CageRadius} (n * \text{WireRadius} / \text{CageRadius})^{1/n}$$

where 'n' is the number of wires, and

WireRadius is the radius of an individual wire

2023-0812

AEØEN

## ABS vs PVC Separator Rings and Construction Tips:

It is appropriate to discuss separator ring material options here. The two most common and inexpensive choices are PVC and ABS pipe, cut into rings about 7/16" to 1/2" wide, and then drilled with a 7/64" drill bit to accept 4" tie-wraps (zip-ties) of about 18 lb strength, to secure the wires to the rings. Even when the tie-wraps are tight (but not yet glued), the rings can slide along the cage of wires for even spacing. At that time apply a small bridge of *The Welder* contact glue across the tie-wrap to the wire on either side of it. It adheres to the wires and nylon tie-wrap very well, but can be removed with some effort.

*Before* cutting the pipe it is *important* to add reference lines along the side of the pipe, parallel to the axis. With white PVC a Sharpie pen can be used, with black ABS a white or yellow paint pen is best. If you intend to build a 4-wire cage then you will need to mark lines every 90° around the pipe. For a 6-wire cage mark lines every 60° around the pipe. The amount of effort is almost the same no matter how many wires you opt for, so I recommend six. It can be tricky to keep the lines exactly parallel along the entire length of the pipe, and I had to build a simple temporary jig to accomplish this. A hint of slope to the lines is harmless as long as all the lines have the *same* slope, since when you later the rings the line spacing is still uniform *for each ring*. Thus each ring has its own reference marks for the next step – drilling holes on either side of those marks for the tie-wraps to pass through. See the two illustrations at right. **Chapter 18 offers detailed ring construction tips.**

My online study of ABS found that it has similar RF properties to PVC. My DC resistance measurement showed infinite resistance on a 2M ohm scale. There is very little total mass present in a dozen separator rings (they are very light-weight) and I have not noticed any RF heating problems of any kind at 100W. (Later: 800W has been transmitted and no heating of any kind has been evident.)

Thus I chose ABS over PVC because it is stronger, more impact resistant, and has **a temperature range of -40°F to 160°F (-40°C to 71°C)**, compared to PVC which has a range of 32°F to 140°F (0°C to 60°C). Below freezing PVC becomes brittle, which is why trailers and mobile homes use ABS for drain and vent pipes (but *not* potable water). Trailers are not always heated and drain pipes extend below the floor and are thus exposed to the coldest weather. Both ABS and PVC should be painted to protect them from long term UV exposure, although I have seen bare PVC vent stacks on residential roofs that are many decades old and still look fine. Both materials are available in all pipe diameters of interest for caging.

Ring (or cage spreader) interval spacing is whatever works best for the builder. I have used 7:1 and 14:1 interval-to-diameter ratios and both worked well. The rings need to be close enough together that the wires between them stay parallel and don't twist into an hourglass-shape, or deform or flop in wind. ***Both my 10m and 15m Hen-Deltas have 6 rings per side.***

2023-1208 Addendum: Today I tested a 6" diameter, 1/2" wide ABS ring in a 900W microwave oven (2.45 GHz) and 'cooked it' for 30 seconds. The ring came out completely cool to the touch. Another longer test in an 1100W microwave oven also showed no heating in the ring at all. This strongly suggests that this kind of foam-core ABS pipe is a fine choice as caging ring material, and that legal limit power at HF frequencies should not cause any heating problem in the ABS ring material.



# (16) FRACTIONAL CAGING VS BANDWIDTH STUDY:

2023-1129: Is caging a linear function of fraction caged, an S-curve, or what? I built a special 10m, 6-wire, 18-gauge Hen-Delta antenna to find out. It **has moveable** 3.5" cage spreader rings held temporarily in place with small 4" tie-wraps. The top spreader ring was fixed in place.. At the beginning of this experiment (SWR curve-1 below) five spreaders were pushed to the top of the Hen-Delta down wires (side wires) to form a minimal 10" length of caged wire (see blue frame 1 at right). The wires below were all tie-wrapped together into a tight bundle every 8" or so. At each successive cage test length – in 16" steps – the bundled wires were cut free of their tie-wraps (zip-ties) one by one, and the spreaders were moved down the wires. Every 30" or so the wires were tie-wrapped to keep a spreader ring at that point and maintain an orderly cage (see blue frames 2 and 3 at right).

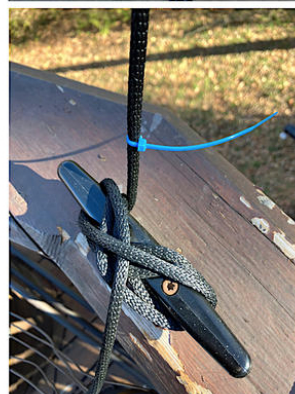
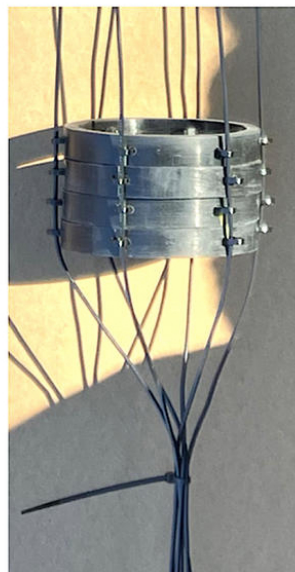
At each +16" test length step the antenna was re-tuned to achieve an SWR of about 1.06 to 1.07. (Curve-3 chanced to tune to an SWR of 1.01 which was very nice, but I had to compensate for that by measuring its bandwidth at SWR 2.95 rather than 3.00, so that its bandwidth would have the same delta-SWR as all the others.)

Thus the first bandwidth was at minimal caging length of 10", the second at 26", the third at 42", and so on. You will note that each bandwidth curve **broadens** as more of the downwires are unbundled and contribute to caging, as shown below. **Compare the bandwidth of the first one, BW-1, with the last one, BW-8 on the next page!**

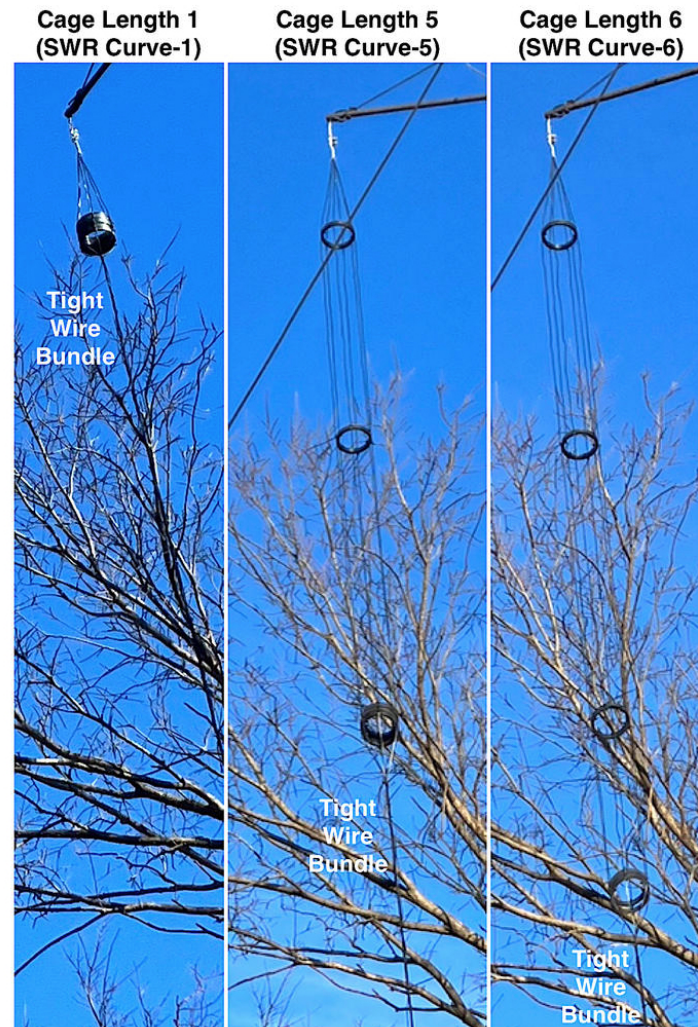
Loose caging tie-wraps allow rings to slide down sides

Ring stopper tie-wrap

Blue marker tie-wrap assures height above ground is always the same

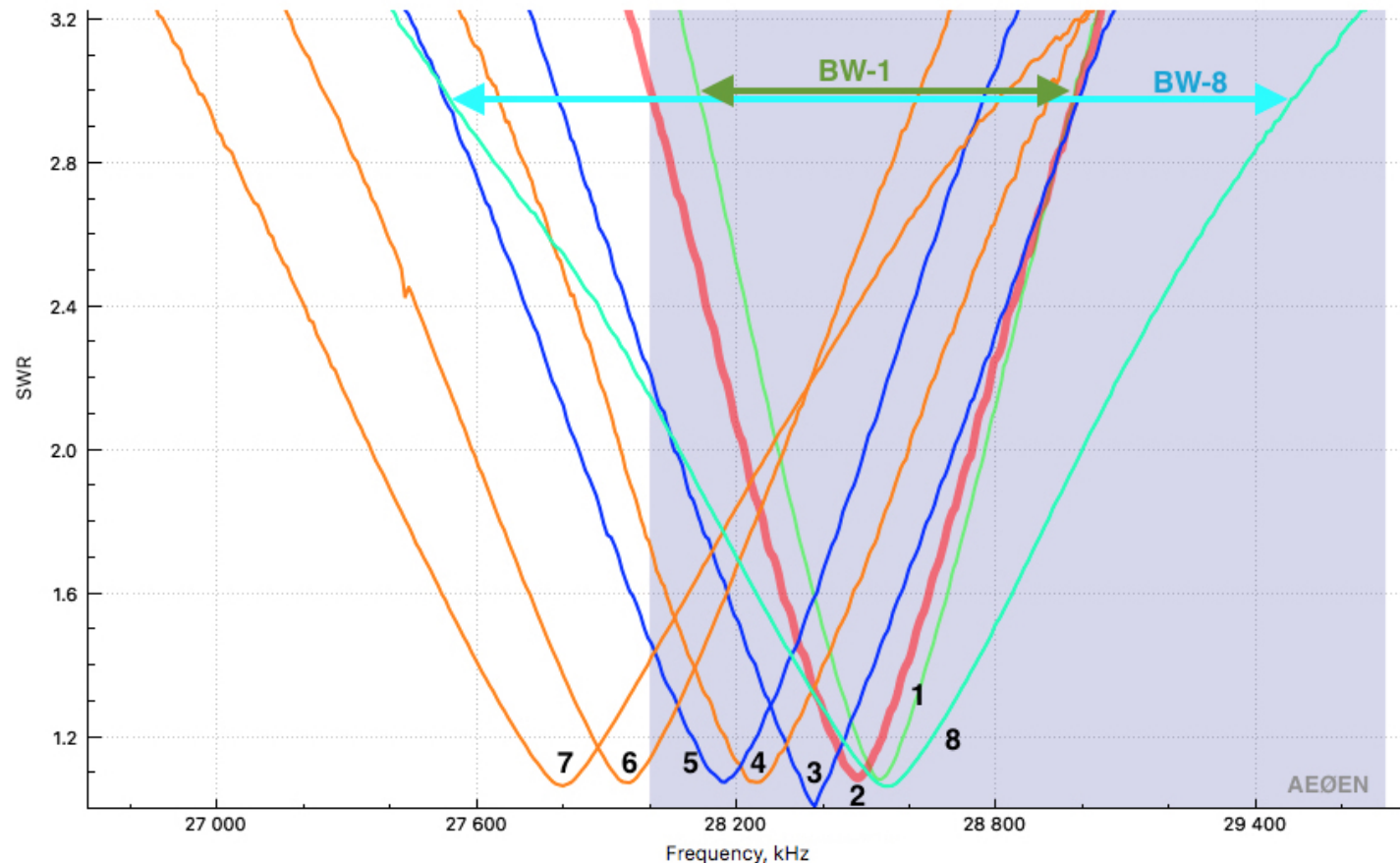


Cage Length Test Sequence Example Photos



Test length interval was 16", separator ring spacing about 30"

## Raw Data for Fractional Caging Study

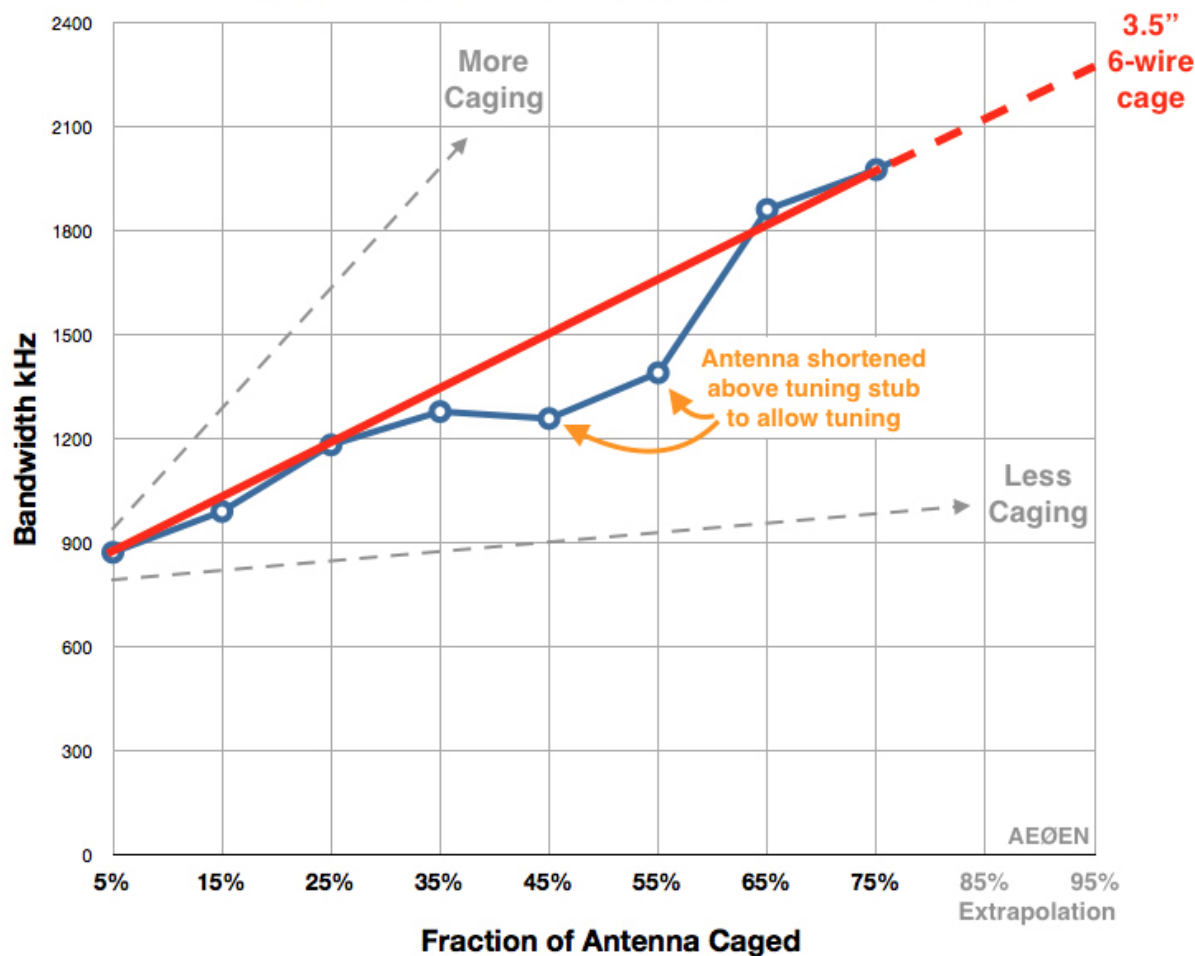


ERP (Effective Radiating Power or 'antenna efficiency') vs SWR: 1.0 = 100% 1.2 = ~99% 1.6 = ~95% 2.0 = ~90% 2.4 = ~83% 3.0 = ~75%

It is not important that the curve minima's are spread across some of the spectrum space – their *shape* is not altered by this and it resulted in an enormous time savings... The study was, in fact, *very* labor intensive and took all day (12+ hours), with probably fifty trips up and down stairs and each trip requiring that the subject Hen-Delta antenna be lowered, either successively-tuned or cage-stepped, and then raised back up to the test height of 40-feet above ground (a little more than one wavelength). To add injury to insult the adjustment range

of the tuning stub was exceeded twice and the length of the down wires had to be carefully shortened to provide additional tuning range. That took a lot of time, and also impacted some of the data (the 45% and 55% data points were shifted), but this 'stumble' was unavoidable – a much longer tuning stub than 24" would have been handy but I was repurposing old parts for this one-time experiment.

### FRACTIONAL CAGING vs BANDWIDTH (3.5" cage of 6 x 18g wire)



**Conclusions:** As you can see by the red line above, **caging appears to be a linear function of the fraction of the antenna caged**. It is *not* necessary to cage 100% of an antenna to see a tremendous bandwidth gain! For example, as shown in the graph above, using a 3.5" 6-wire cage (results vary with cage size

and wire count), caging only 65% of the antenna can double the bandwidth (from 900 kHz at far left to 1800 kHz at 65%). This may vary slightly by antenna design and band (wavelength) but the essential point is: **The larger the fraction of the antenna that is caged the greater the bandwidth improvement!**

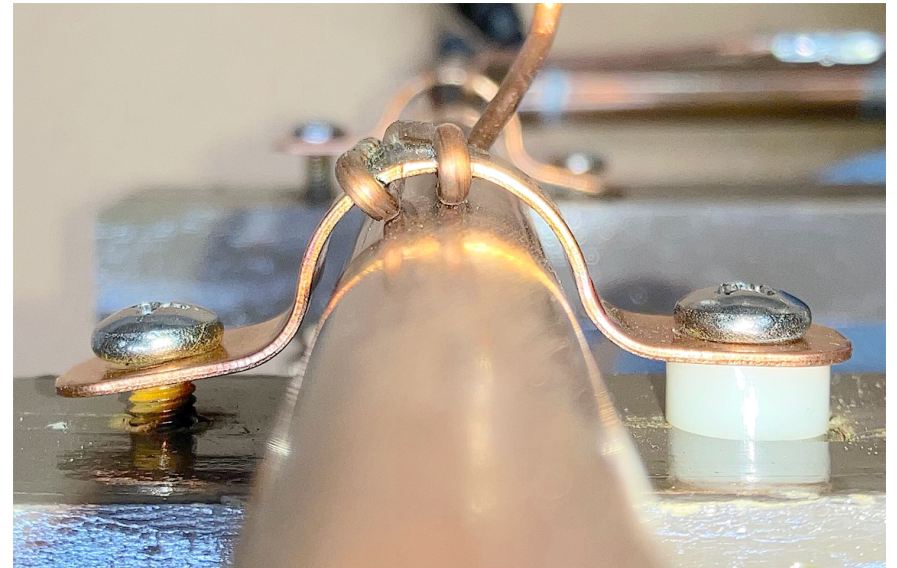
Specifically as related to Hen-Delta antennas, these results show *why* it is *not* necessary to use a 2- or 3-pipe top element since very little bandwidth ‘opportunity cost’ is given up by using just single 1/2” copper pipe – it’s length is only 12% of the total loop circumference *and* the 1/2” pipe is still a significant 5/8” in diameter. If maximizing bandwidth is a high priority, rather than use multiple

(heavy, expensive) copper pipes for the top element, instead use a larger cage diameter with at least six wires for the ‘down wires’ (see Chapter 15 above). Because the Hen-Delta is a *loop antenna* these results should logically apply to *all* loop antennas. And since dipoles have historically been caged, it seems certain that these results would apply to *all* antennas.

## (17) NEW TUNING STUB DESIGN V2.0 AND CONSTRUCTION TIPS:

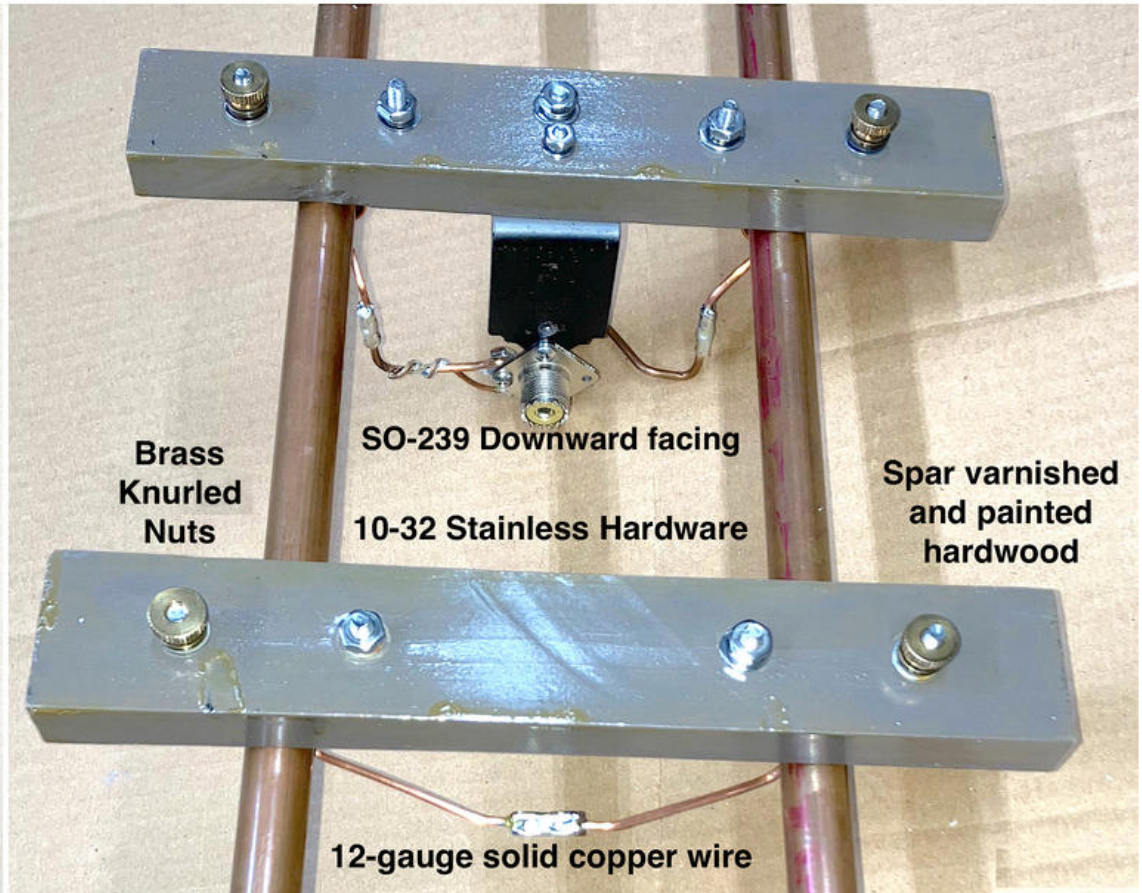
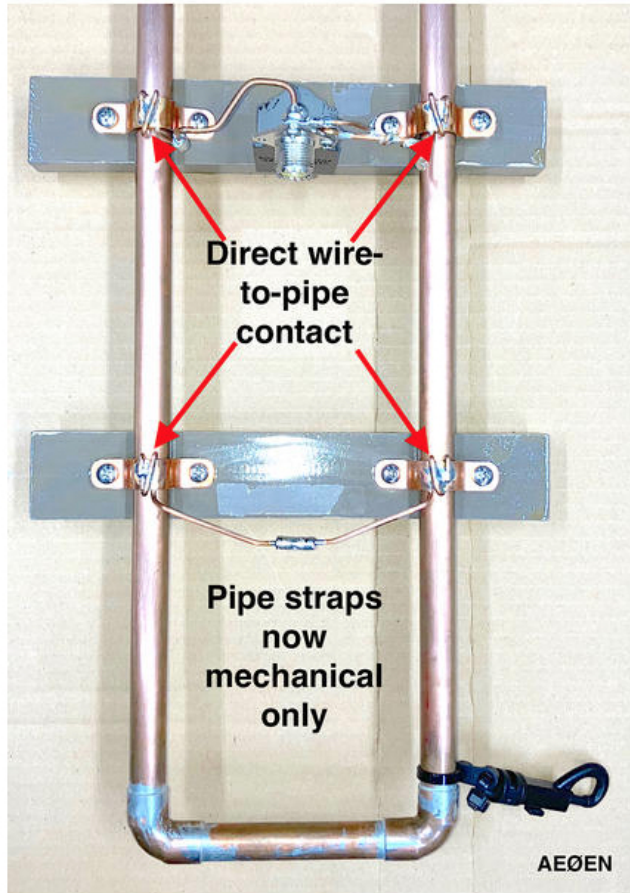
2023-1202: The original v1.0 design has worked very well but had some minor shortcomings which the new v2.0 design addresses. The primary concern was that the commonly available hardware store pipe straps (NIBCO 624 recommended, not the thin ridged straps) were *copper plated steel* and tended to rust along the thin edges or where their mounting holes had been enlarged (solid copper straps have recently become available on Amazon but their strength and deformability for this purpose is untested). Being in the RF path this might someday create a problem. A temporary workaround solution (v1.2) was to wrap a single soldered copper wire front-to-back around the strap to provide a solid RF path and to bypass the steel interior (see Chapter 11). This worked well and was probably sufficient, but I didn’t care for the steel strap being in the RF path *at all* – what is the RF power handling capacity of the copper plating on a steel strap? Version 2.0 removes the pipe strap from the RF path entirely and it now is relegated to a *purely mechanical role* in forcefully compressing the 12-gauge contact wires against the copper pipe. This compression is *so forceful* that when the knurled nuts are firmly finger-tightened, neither ‘slider’ will move even with both thumbs applying considerable force. If you contrast this forceful contact to that of a gentle rotating wiper contact in an antenna switch rated at 1000 watts (225V, 4.5A)\*, it suggests that the v2.0 tuning stub contacts should be capable of supporting full legal limit power (275V, 5.5A)\* *and then some!* I have used 800W without incident or concern.

In V2.0 the SO-239 connector is also now facing *downward* to relieve bending stress on the coax where it exits the PL-259 connector – the coax now hangs straight down (at the balun also). The following illustrations detail the construction and is my best tuning stub to date.



\*See various calculators here: <https://www.hevener.org/index.php/calculators/>

## Improved v2.0 Tuning Stub: Front and Rear



**Copper Cleaning:** In 18 months of operating various versions of the tuning stubs I have *never* become aware of a need to clean the copper pipe or the sliders' contact wires. It may be that the contact points are under so much compression that oxidation does not form there, or forms around those points, sealing them? Or perhaps operation at 100W or more clears away oxidation at the contact points? Whatever the reason, I am pleased not to have to fuss with such pesky issues often. When the time does arrive that they need to be cleaned, first mark the back side of the pipes with a felt pen or pencil, loosen the knurled nuts slightly, then move the sliders back and forth a couple of times, returning them to align with the pen or pencil marks. That will likely be sufficient as the mov-

ing contact wires scratch the pipe. Beyond that, just a few strokes with a fine grit foam sanding block or fine emery paper would work. For the contact wires themselves, see step 'G' on the following page. Dielectric grease ('no-ox') might be a helpful barrier to slow contact oxidation. I don't know how well it holds up outdoors in the weather.

**Thermal Cycling:** Those knurled brass nuts (right) under spring tension may *loosen* over several months time due to day-night thermal cycling, so check them every couple of months or use a tiny amount of removable (blue) thread lock.

### Photo collage of construction tips:

All soldering was done with a butane 'pen torch' with a fine flame. Use only modest amounts of solder.

**A, B)** To straighten a scrap length of 12-gauge wire (A) use a rubber mallet to tap the wire as you roll it back and forth on a flat surface. In a couple of minutes it will be straight and neat (B).

**C)** With a 7" length of wire, form a tight bend and crush it almost closed. Open the gap slightly with diagonal cutters if necessary. Slide it onto the pipe strap and crush the wire to the strap. Align the wire so that it will be parallel to the pipe and solder it to prevent movement.

**D)** Tightly fold back the wire at a slight diagonal and solder it to prevent further movement.

**E)** Fold the wire again to create a second parallel wire contact about 1/4" from the first wire.

**F)** Solder the underside contact wires to prevent movement. Use only a modest amount of solder.

**G)** The needle nose pliers will have slightly marred the surface of the contact wires when tightly wrapping them around the strap. Wrap some fine sandpaper around a piece of scrap 1/2" copper pipe and sand down the wires to remove any high spots and to create a cylindrical profile for the tuning stub's copper pipe to sit in.

**H)** Close up: After sanding you can see that any high spots have been removed and a cylindrical profile surface has been created to make contact with the copper pipe of the tuning stub (red arrows).

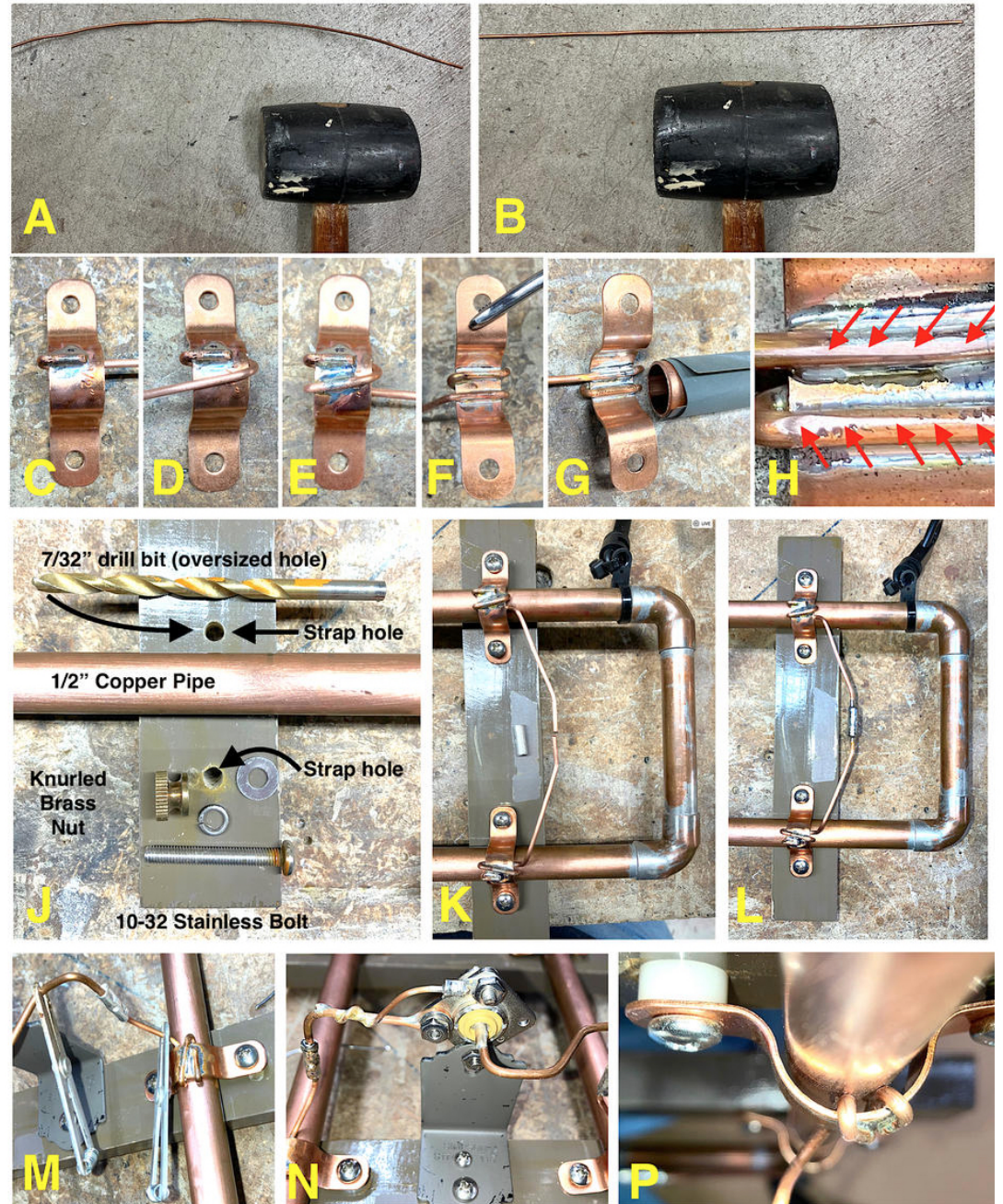
**J)** The hardwood 'sliders' (sliding contacts) have been previously painted and spar varnished for weather (moisture) resistance. Use only stainless or brass hardware (brass knurled nuts are less costly than stainless).

**K, L)** Using the stainless hardware, mount the strap-and-wire assemblies to the sliders, shape the wires into a neat shallow-V (for dimensional adaptability), trim off the excess wire, and crimp on a 'butt connector splice terminal' as shown in (L).

**M)** Solder all crimped 'butt connectors' being careful to use heat sink clamps to prevent other nearby soldered connections from melting.

**N)** The SO-239 is mounted facing downward using an L-bracket. Note that TWO bolts and wires were used to secure two SO-239 ground connections so that any twisting/torquing of the SO-239 when attaching or removing the PL-259 would not loosen the bolts

### Improved v2.0 Tuning Stub Construction Tips



(which *does* happen if you only use one bolt). The heavy wire you see on the SO-239 is actually 10-gauge solid wire – this connector was removed from the v1.0 tuning stub to be re-used here. 12-gauge solid wire works, too.

**P)** This close-up photo of the two contact wires under compression shows them both making solid contact with the pipe. While one wire would be sufficient, I preferred redundancy and more contact surface for future high power test-

ing. Note the presence of the *nylon spacer* on the fixed strap bolt (Amazon: ‘Nylon Round Spacer Standoff Assortment’). This strap was seated awkwardly on the pipe such that only one wire was making contact with the pipe. Adding the nylon spacer raised the strap so that both wires made solid contact. The spacer may or may not be needed in other circumstances.

Optional: If you would also like to have knurled *bolt heads* consider these 1” and 1.5” long bolts by Taylor Toolworks (Taytools) in 10-32 and other sizes available on Amazon. These would prevent the bolt *head* from spinning as you try to tighten or loosen the knurled nut, although I have not seen that occur often and have not tried them:



“Stainless Steel Diamond Knurled Thumb Screws Knobs with Straight Shoulders”

[https://www.amazon.com/gp/product/B07XF7262S/ref=ox\\_sc\\_act\\_title\\_1?smid=A1F0ZX9W2WURWY&psc=1](https://www.amazon.com/gp/product/B07XF7262S/ref=ox_sc_act_title_1?smid=A1F0ZX9W2WURWY&psc=1)

## (18) How to cut large diameter ABS or PVC cage separator rings, and final construction details:

2023-1207: Since my memory isn’t getting any better as I age, I thought I would take some photos of this process to remind myself exactly how to do this again in the future, should I need to. I will share my notes with all of you antenna builders with the caveat that *you alone are responsible for shop safety!*

Let me make one strong recommendation: **It is DANGEROUS to try to cut rings from the last 6” of pipe!** Your fingers get much too close to the saw blade! If you need more rings than one piece of pipe can safely provide – *buy another piece of pipe!*

With my **10” Radial Arm Saw** I was able to get about 28, 1/2”-wide separator rings from a 24” long piece of 6” ABS ‘riser pipe’ (\$10 at a hardware store) with 6” of pipe remaining. That would translate into about 35, 3/8”-wide rings

which I suspect would also work well, but I was more concerned with strength than weight. Each cut wastes ~1/8” due to blade width. On my radial arm saw I use an 80-tooth Freud LU79R010 carbide tipped blade with a non-aggressive +2° hook angle to make fine cuts. I seem to recall that *negative* hook angles are even less aggressive, but I couldn’t find such a blade. Too great a *positive* hook angle makes the blade-motor assembly want to pull itself into the material, sometimes *surging instantly* towards the operator (this happened to me years ago with a prior, more positive hook blade). This is alarming, happens too quickly to control, and can tear up the material as well! So check your blade design, be certain the blade is still *sharp* or replace it (important), and always *be careful!* Note: I don’t have or use a ‘table saw’, so if that is your shop saw you are on your own! A large band saw might work if you build a jig to hold the pipe square and secure... but I don’t have one.

## Radial Arm Saw Instructions

**A)** The first and most important step is to build a special pipe-sized or over-sized stop board for the saw AT LEAST as large as the pipe diameter. The stop board's position controls the width of each ring. All three pieces of the stop board must be solidly screwed together.

**B)** Equally important is that the stop board be *shimmed* so that the pipe face is aligned to (touches) the board at all points around the pipe, front and rear. Clamp the stop board to the saw table when cutting rings.

**C)** A 4x4 backstop supplements and is clamped in front of the saw's small guide rail on the table so that the rotating pipe can't 'climb' up the guide rail.

**D)** With saw OFF, practice turning the pipe so that it stays in contact with the stop board. Turn ON the saw and cut into the pipe to roughly top-center.

**E)** Lock the blade in position at its present location.

**F)** Slowly rotate the pipe against the blade, cutting the ring as you turn the pipe. When the cut is nearly complete slow down the rotation. Turn OFF the saw as soon as possible. **DON'T MOVE ANYTHING until the blade stops!**

**G)** UNLOCK BLADE POSITION (see step 'E') AND RETURN BLADE TO REARMOST 'HOME' POSITION. Remove the cut ring and clean the debris from the table.

**H)** File off any irregular bumps from the cutting process. Some of this may be melted ABS. The entire pipe face should be smooth and free of any irregularities.

**J)** Look for any debris build-ups on the table, the pipe stop, or anywhere it would affect the next cut.

**K)** With the saw OFF, before making another ring, test rotate the pipe to check for snags and bumps that might disrupt the next cut. If it is okay then go to step 'D' and repeat.

**BE CAREFUL!!! NO ANTENNA IS WORTH A TRIP TO THE EMERGENCY ROOM!**

**L)** When all rings have been cut, deburr the rough inner and outer edges of each ring using a coarse foam sanding block or other means.

**M)** Drill 7/64" holes on either side of the 60° paint pen lines (yellow lines on the pipe above) around the 'equator' of the ring, like on this 3.5" ring below...

## How to Cut ABS Pipe to Make Large Cage Spreader Rings





N) To insert the rings into a cage I create two sets of six parallel wires slightly longer than needed and stretch them horizontally a few feet apart in my work room about chest-to-head height. Both ends of each wire bundle (6 wires per bundle in this case) should be soldered together *first* to help keep everything orderly. The wire bundles will form a catenary arc rather than a straight line, but that is good enough for now and much easier to work with than crawling around on the floor.

O) Space out the rings appropriately every few feet and tightly tie-wrap (zip-tie) the rings to each wire using 4" ties of ~18 lbs strength each, being certain to keep all the wires correctly positioned, as shown above. Do NOT glue them yet. See next page.

By the way, when glued, two of these rings (one on each side of the antenna) may be placed upon large hooks and the lower portion of the antenna hung below the hooks – ‘parked’ or ‘draped’ over a deck railing or other structure. The ABS rings and six glued wires are quite strong.

**Final Cage Construction Details:** (The letters in the photo match the descriptions below.)

**A1)** Use bungee cords to stretch the caged wire bundles on a floor. This eliminates the catenary arc for final alignment. In this photo the far ends have had two-hole lugs crimped and soldered, and those lugs are used to secure the ends to an anchor point.

**A2)** Tension all the wires by pulling out any slack, wire by wire and segment by segment. Try to keep the rings perpendicular to the wire as you do this. Any slack should be moved, bit by bit, to the bottom end of each cage. The wire will slip through each tie-wrap with just a modest pull.

**A3)** Align the rings perpendicular to the floor and to all wires. Repeat step A2. When the wires are ALL reasonably taut and the rings ALL nicely aligned, place a bit of glue (I use *The Welder* contact cement) on the tie-wraps of the uppermost four wires ONLY of each ring of both cage bundles. Don't try to glue the bottom two wires yet or you will get glue on the floor! Straddle the tie wrap with the glue, from wire to tie-wrap to wire, about a 3/8"-1/2" long glue bridge. Wait a few hours for the glue to dry, roll over the cages 180°, and glue the remaining two wires. Wait a few more hours for the new glue to dry.

**B)** Carefully measure the length of each cage using a tape measure down the middle of the cage. It doesn't matter exactly how long the cages are *as long as they are nearly the correct length and equal, give or take 1/4"-1/2"* (the Hen-Delta is very forgiving and the tuning stub will 'absorb' any modest length alterations). I seem to remember that these 15m cages were ~201" long, but I didn't record that length as it isn't important. Trim the excess length of each cage, crimp (or double crimp) and solder on the two-hole lugs. I prefer lugs with 1/4" holes, 5/8" apart (center to center), and hex head (*not* Phillips head) stainless 5/8" steel bolts, lock washers, and nuts. Being hex head I can tighten them *very* tightly with two socket wrenches. Being two-hole the bolts will not loosen over time as a single hole lug would do (and has).

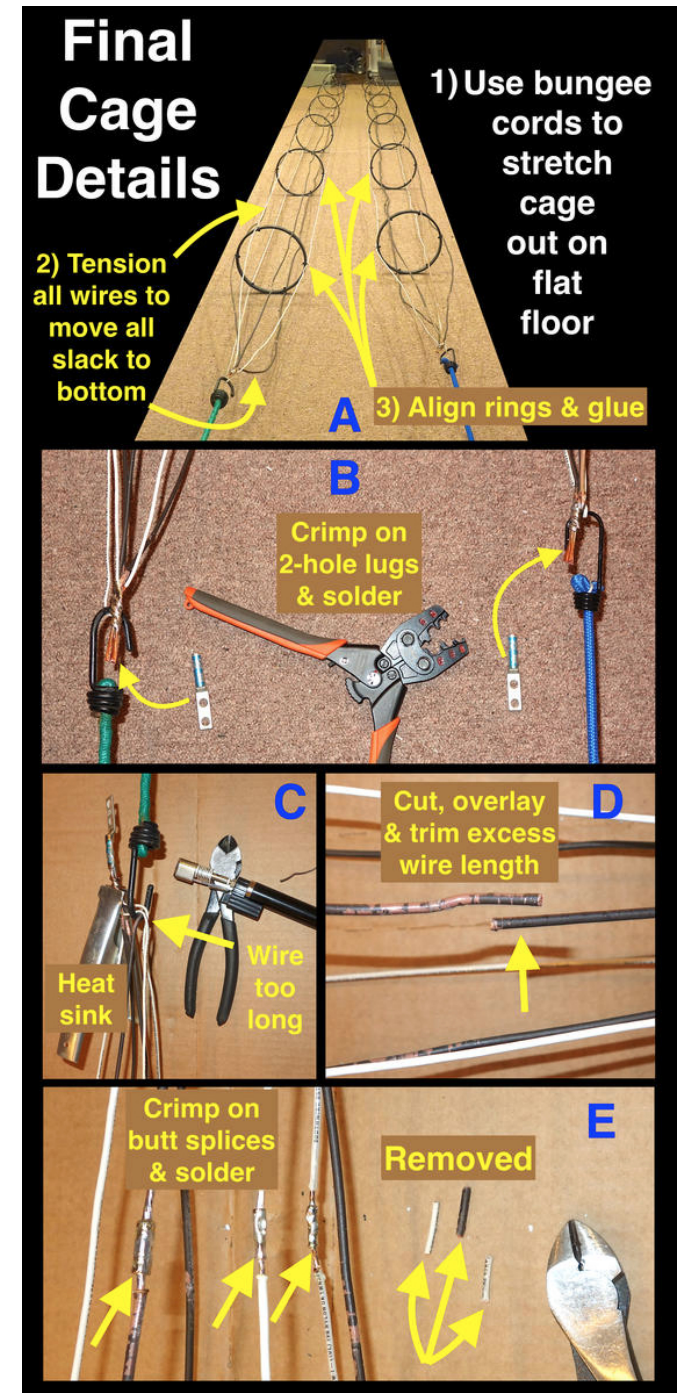
**C)** Note the large heat sink clamp used when soldering on the two-hole lug. All the wires are constrained by this main solder joint and you don't want the joint to melt as you attach the lug – the wires might pull apart! A pencil torch quickly solders the lug (use plywood underneath for solder drips). Also notice that the two white wires (yellow arrow) appear to be too long – it is inevitable that a couple of wires will be.

**D)** Cut the long wires then trim off the excess length. It's rarely more than 1/2"-3/4" or so. *It's best to do this one wire at a time so the cage doesn't try to distort itself.*

**E)** Strip the wires and crimp on butt splices and solder them. Repeat until all wires that were too long (and thus slack) have been trimmed. I had to trim three wires on one cage and one wire on the other.

Note that the brown (painted) wires are 12-gauge and the white wires are 14-gauge. That's because the 12-gauge wires were re-used from the original 1.1" cage, and the white 14-gauge wires are new. Mixing similar gauges, if done with a degree of mechanical (load carrying) symmetry, isn't a problem. Neither is splicing together two short wires to make a long wire, which I did once – but I always solder my connections. By the way, per the calculators at <https://www.hevener.org/index.php/calculators/>, 3 x 12g wires PLUS 3 x 14g wires is the equivalent of one 5-gauge wire with respect to wire resistance (mixed gauge wires are insignificant with respect to effective cage conductor diameter).

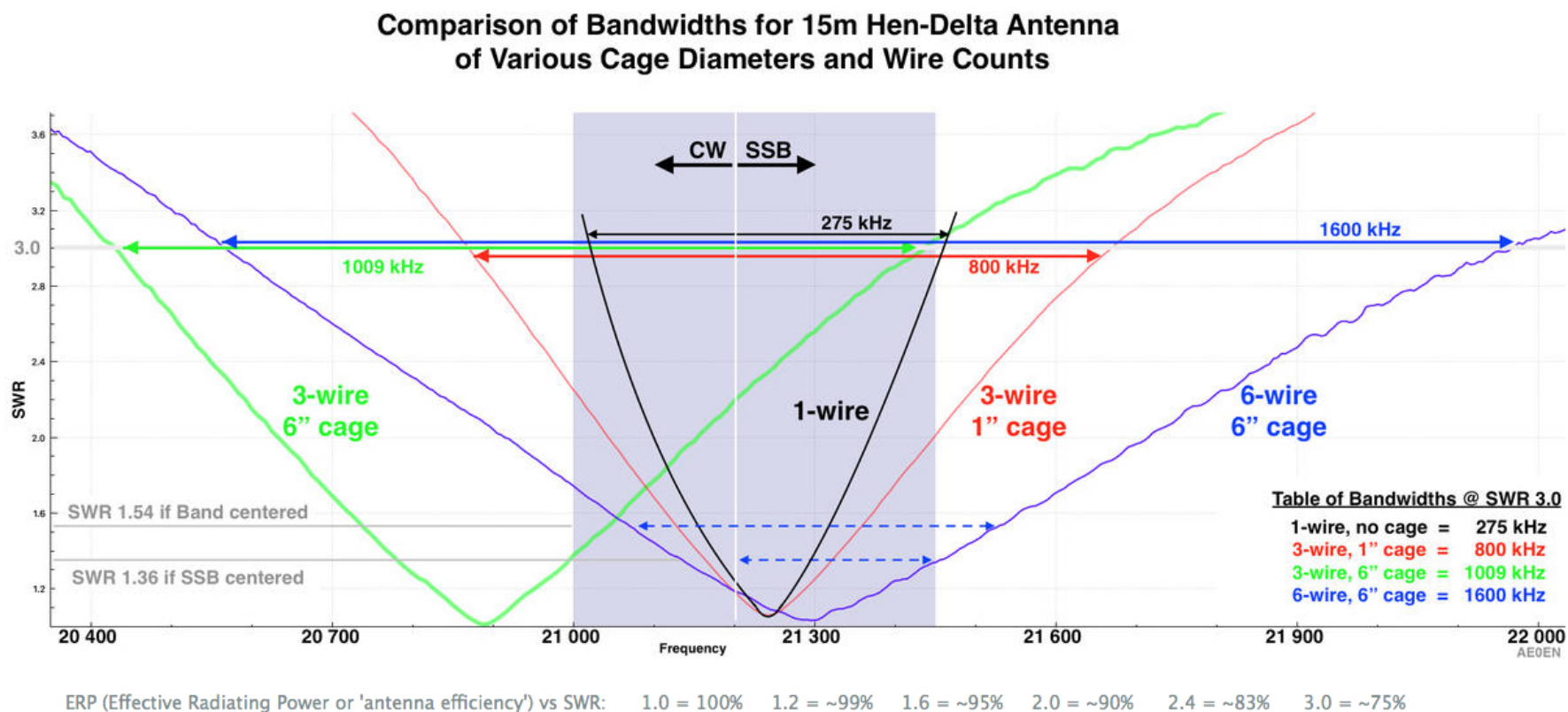
See Chapter 20 below for the final 15m, 6-inch diameter, 6-wire caged Hen-Delta 'as-built' dimensions.



# (19) 15m HEN-DELTA WITH A 6-WIRE, 6" CAGE:

2023-1208: As with the 10m Hen-Delta above, **caging at a ring diameter of 1% of wavelength (~4" for 10m, ~6" for 15m) provides tremendous broadbanding. Above 1% diminishing returns rapidly reduce any further benefit, and I have read one anecdotal comment that 2% of wavelength is the maximum useful caging diameter.** That second percent doesn't buy you much extra bandwidth – perhaps 15%-20% more. A test of my 10m antenna with a 6-wire, 6"-cage of 18-gauge wires (a modification of the Chapter 16 fractional caging antenna) saw an improvement in bandwidth of only ~15% relative to a 3.5" cage, so the 2% of wavelength limit seems true. But if you desire the maximum possible bandwidth, go for the full 2%!

The advantage of wide bandwidth on 15m (a narrow band) is that your antenna is a *highly efficient radiator across the entire band*. If the Hen-Delta is tuned for the center of the 15m band, the worst case SWR is ~1.54, and if centered on only the SSB region the worst case SWR is ~1.36 or a bit less – I think I could get it down to ~1.28 if exactly centered at 21,325 kHz. The numeric SWR 3.0 bandwidths of the various caging configurations are summarized in the *lower right inset table* here...



I find that I can set my manual Palstar tuner to median C and L values and *never have to adjust them again anywhere within the 15m band*. That is also true of the 10m Hen-delta for about the first 500 kHz of the SSB band.

Note that the 1-wire curve was added manually from past data, the rest are all actual saved data runs.

The blue-purple trace is the final run. The resulting tuning table for the SSB region of the above 6-wire, 6" cage (blue-purple trace) is at right. By setting the manual Palstar tuner to C=58 and L=284\* I never have to touch the tuner again on 15m... it's a 'tune it and forget it' bandwidth antenna.

By the way, if you create a dual-band tuning stub such as my 10m/12m version, the tuning table will be somewhat more variable on the first (shorter wave-length) band, but not wildly so.

## 15m Hen-D

| <u>Freq</u>   | <u>C</u>  | <u>L</u>   |
|---------------|-----------|------------|
| <b>21 200</b> | <b>58</b> | <b>283</b> |
| <b>21 250</b> | <b>58</b> | <b>283</b> |
| <b>21 300</b> | <b>58</b> | <b>283</b> |
| <b>21 350</b> | <b>58</b> | <b>284</b> |
| <b>21 400</b> | <b>58</b> | <b>285</b> |
| <b>21 445</b> | <b>58</b> | <b>286</b> |

\*The Palstar roller inductor's *counter* is deliberately backwards for mechanical simplicity, so 299 is *minimum* inductance and 000 is *maximum* inductance. Thus a counter reading of 284 represents very little additional inductance.

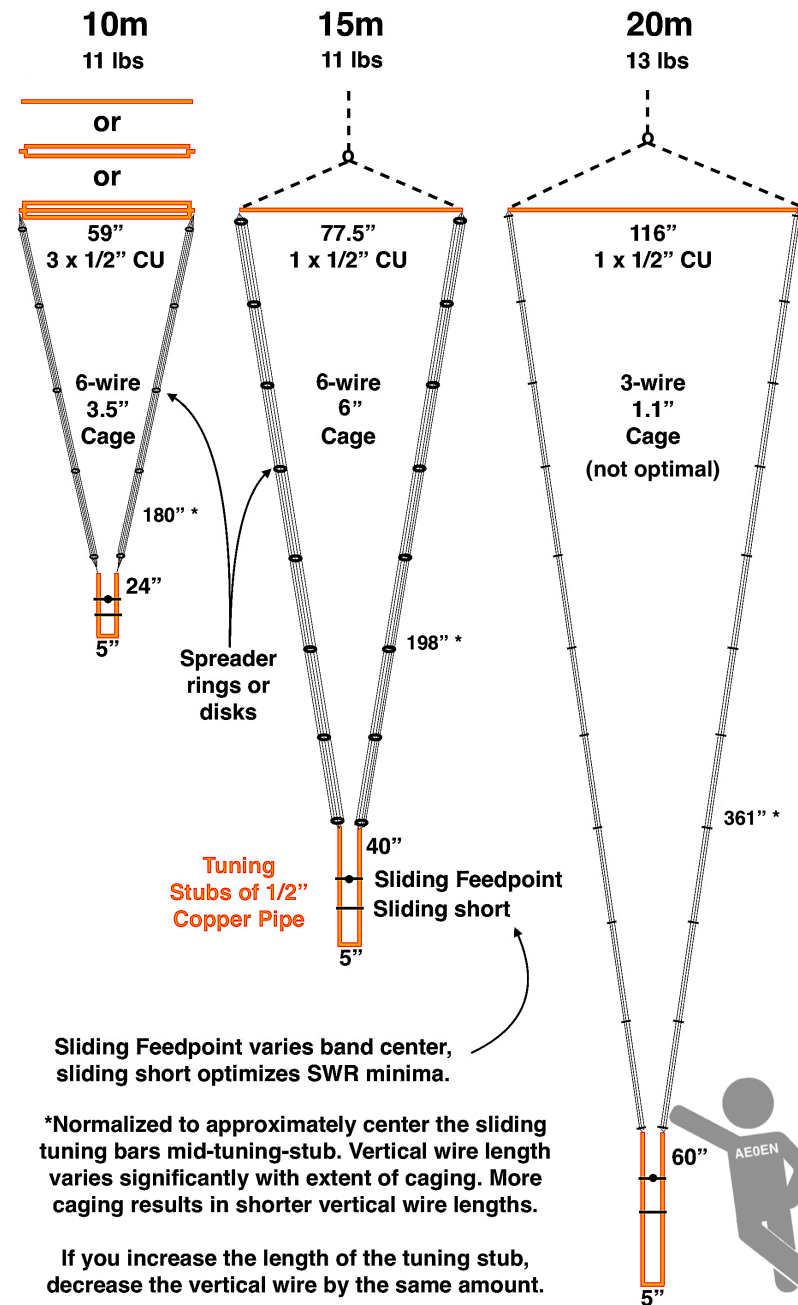
## (20) 10m, 15m, & 20m Hen-Delta Family ‘as built’:

2023-1209: Here is a summary of dimensions for my Hen-Delta family at this time. I may someday build a larger 6" cage for the 20m. The ‘downwire’ lengths *include* the short pigtails on the top element and tuning stub.

Below is the best method of suspending a Hen-Delta from a rope – from the *ends* of the top copper pipe. The pipe carries the weight of the antenna and the padeyes keep the rope in position. Two small stainless steel screws secure each padeye and prevent the rope from sliding inward. This photo collage also shows the 8-gauge copper ‘pig-tails’ used to connect to the vertical wire cages – smaller pigtail wires tend to fatigue and break over time. The 2-hole lugs work *very* well. I crimp them twice and then solder them. You may observe that I put a little contact cement (‘The Welder’) on the knots to prevent the Dacron rope from pulling through under stress – probably unnecessary but it is comforting insurance.



## 6m – 20m Hen-Delta Antennas (as built)



## (21) THE HEN-DELTA TUNING STUB AND TUNING PROCESS:

2023-1211: V2.0 Tuning stub photo collage for the 10m band. Other bands are identical except for the length (height) of the copper pipe. See Chapter 17 above for construction details.

a) #10-32 brass knurled nut used to tighten or loosen the tuning slider clamps.

b) close-up of the dual 12-gauge contact wires. The RF path is only through the wires so the copper-plated steel pipe strap serves only a mechanical purpose. If the edges of the steel clamp rust slightly it is only a cosmetic issue. Note that the right side bolt has a nylon spacer to raise that side of the pipe strap. This may or may not be needed to optimize the seating of the contacts.

c) The connection 'pigtails' are 8-gauge solid copper wire. I have found that smaller gauge wires eventually break, especially if twisted. I have been pleased with these two-hole lugs with 1/4" holes spaced 5/8" apart. I found that single-hole lugs will eventually loosen over time from the swaying and twisting of the vertical antenna wires. With two-hole lugs this doesn't happen. There is also more contact surface. Note that the 6" length of the 'pigtail' is *included* in the overall length of the vertical wires –which also applies to the 'pig-tails' on the top copper pipe. Thus the vertical dimensions shown in Chapter 20 are 'pipe-to-pipe' lengths.

d) (not shown) During tuning stub construction, cut two 2x4's to a length of 4-3/8" and use them to hold the pipes parallel and correctly spaced. The lower 1/2" pipe is just a little shorter than 4-3/8" to fit into the elbows.

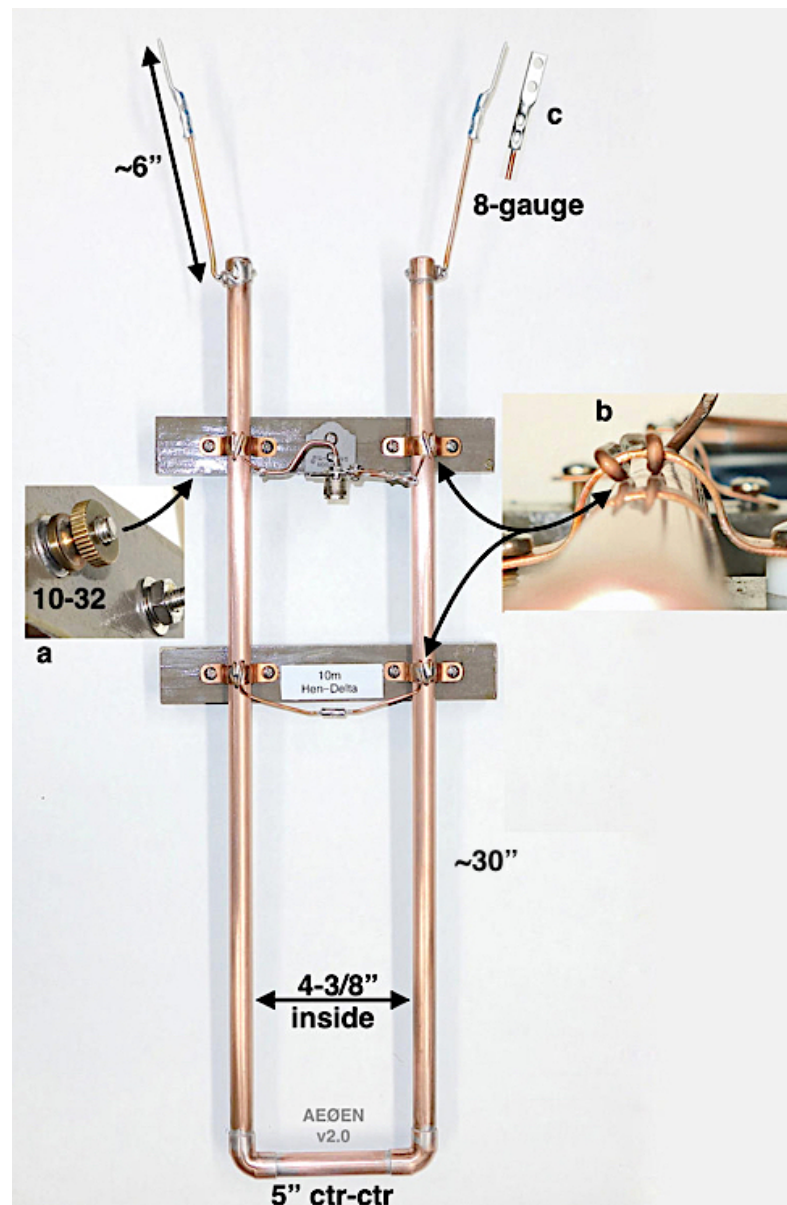
e) The ~30" height of the tuning stub is not 'cast in concrete' but is a good choice. It may be altered to avoid having to trim the bottom portion of the 'down wires'. I do not know what the *maximum* length for the tuning stub might be as a fraction of the wavelength of the antenna – the Hen-Delta is a very forgiving design – but I intuitively suggest not exceeding 36" for 10m.

### Tuning Process:

Tuning a Hen-Delta antenna **requires the use of a graphing antenna analyzer or VNA**. There are many brands of varying quality and price. I use a **RigExpert AA230-Zoom** and the companion **AntScope 2.2 software** (PC or Mac), which connects to and controls the RigExpert over a 10' USB cable.

**The antenna must always be analyzed at operating height above ground. Then lowered for tuning, then raised again for re-testing, repeatedly.**

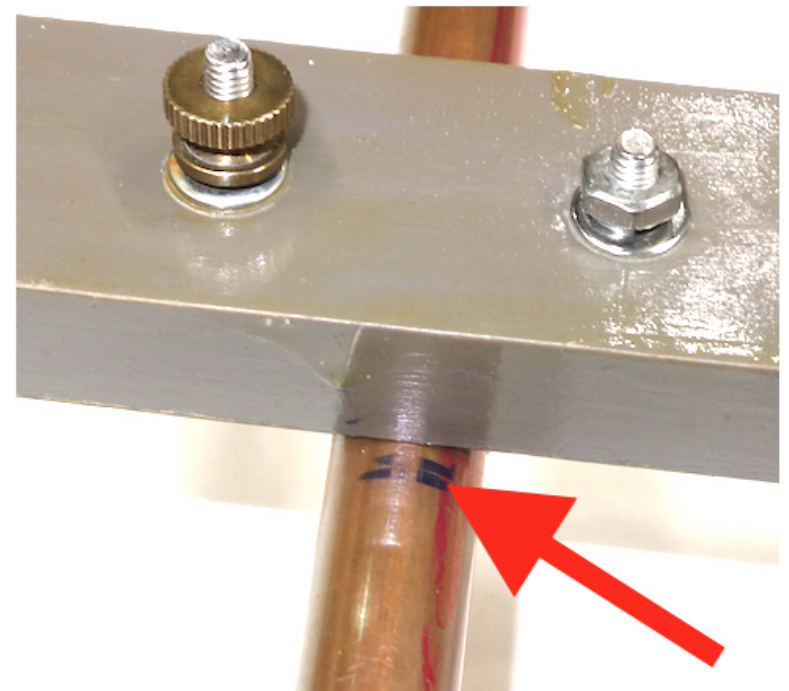
There are two phases to the tuning process, described in detail on the following pages...



**First**, the SWR curve (next page) needs to be **shifted laterally** left or right to a point *somewhat near* the desired center frequency, which will depend on the width of the band in question, the extent of caging, and whether there are portions of the band of special interest to you. That might be SSB, CW, Data, or a blend of all of them. If you wished to cover *the entire band* at low SWR then you would wish to maximize the extent of the caging of the Hen-Delta. Due to diminishing returns, the maximum useful cage diameter is about 2% of wavelength, but 1% of wavelength – 4" diameter – gets you ~80% of the maximum broadband benefit. A maximum 2% of wavelength cage for 10m would be an 8" cage of six-to-eight 12- to 18-gauge wires (see Chapter 15).

**Second**, the SWR minima (next page) needs to be deepened to be as low as you prefer. I consider anything at or below 1.06 to be sufficient, but all it takes is some time and you can get it down to 1.01 if you wish. But I call your attention to Chapter 14's graph showing a 'semi-tuned' curve (magenta) where the SWR minima is *deliberately* made shallow (SWR ~1.2) resulting in a broader *overall* SWR curve. Under some circumstances this may provide a more optimal solution. Per Chapter 6, 'dual tuning', you could *hypothetically* have an antenna with *one* feedpoint slider and *two* shorting sliders (only one active), one shorting slider with a deep minima and one 'semi-tuned'. *The Hen-Delta is very versatile!*

Since the contact wires are only on the front side of the pipe, you may make pencil or Sharpie **reference marks** on the rear side of the pipe as a guide in tuning, or to remind you where the sliders were if you ever need to move or renovate them. The ink marks can easily be wiped off with alcohol.



My feedpoint slider sporting the latest trend in fashionable ABS rain gear. A similar rain hood shelters the balun connections.



## How to tune the stub:

Referring to the illustration at right:

1) Adjust the lateral position (center frequency) of the SWR curve by moving BOTH the feedpoint slider AND the shorting slider in roughly equal amounts. For example, say your antenna first tests at Curve-1 (orange curve) below. Move **both** sliders (red arrow) in successive tries until this curve is **roughly** centered in the portion of the band of interest (say, SSB) at Curve-2 (red curve)\*. *Don't worry about the **depth** of the SWR minima as you adjust the curve laterally.*

2) Adjust for a low SWR by moving **only** the shorting slider (blue arrows). The minima will deepen with each reiteration until you attain a sufficiently desirable SWR at Curve-5 (blue).

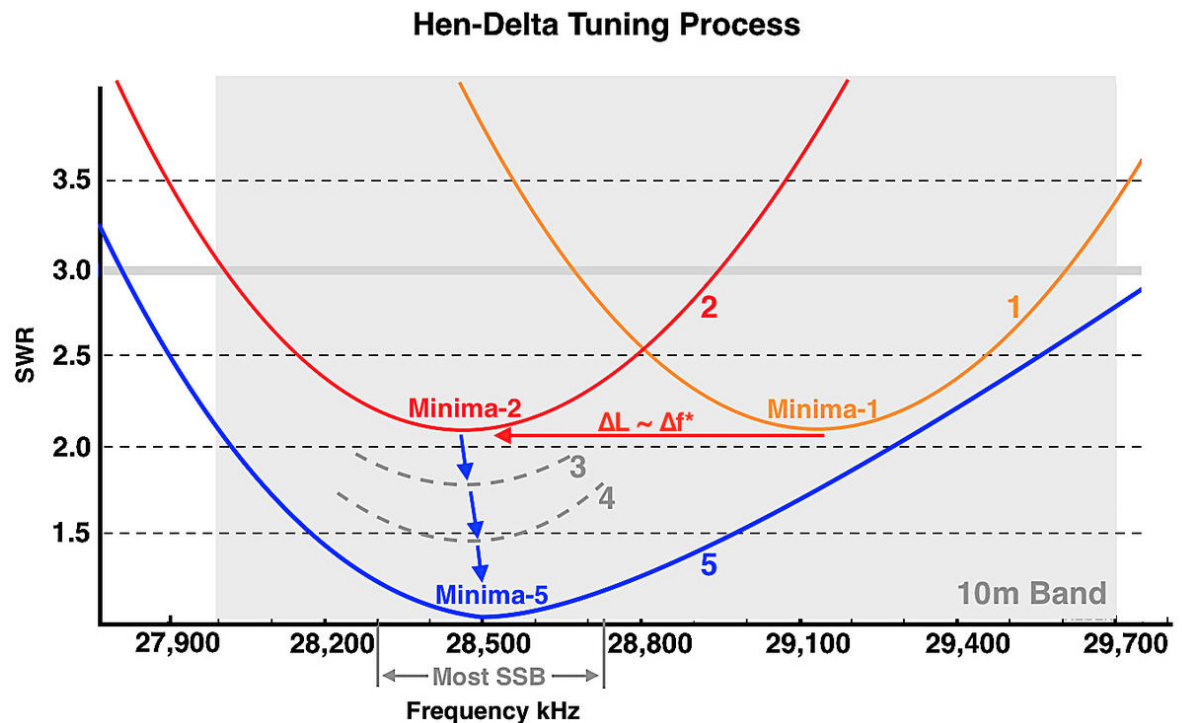
*\*Rather than waste time 'guessing successively', you can calculate the distance for the tuning sliders shift using the absolute value of  $(f_{\text{actual}} - f_{\text{target}}) / f_{\text{actual}}$ . In the illustration at right, Curve-1's frequency is **too high** by about 700 kHz or 2.4%, so lengthen the antenna loop size (top + both sides + half the stub = ~447") by 2.4%. Thus ~10" more loop length is needed to **decrease** the frequency to the desired point. Move both tuning sliders ~5" downward to **add** ~10" of additional length to the loop (ie: ~5" of copper pipe on each side of the stub is 10" in total). A larger loop has a lower frequency. Re-test the antenna. Repeat as necessary.*

Rule of thumb: For my 10m Hen-Delta, every inch of feedpoint slider movement results in ~120 kHz of frequency change (every centimeter results in ~50 kHz of change). This may vary per antenna and will vary by band.

**Key Point:** A *smaller* loop (moving the tuning sliders upward) will increase frequency with a rightward curve shift. A *larger* loop (moving the tuning sliders downward) will decrease frequency with a leftward curve shift.

### Optimizing the minima:

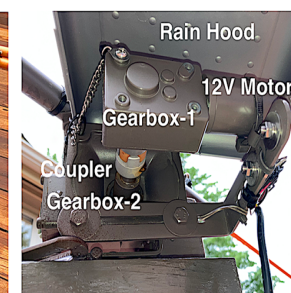
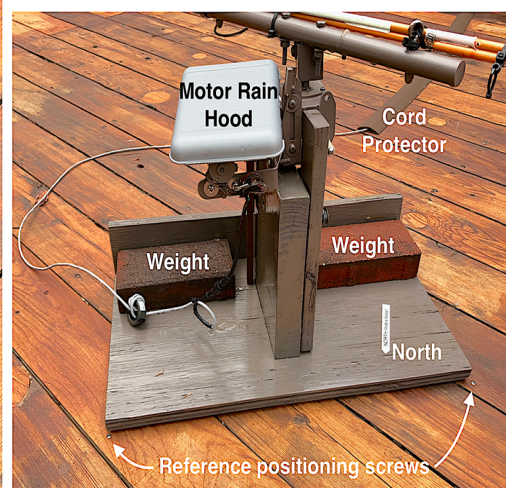
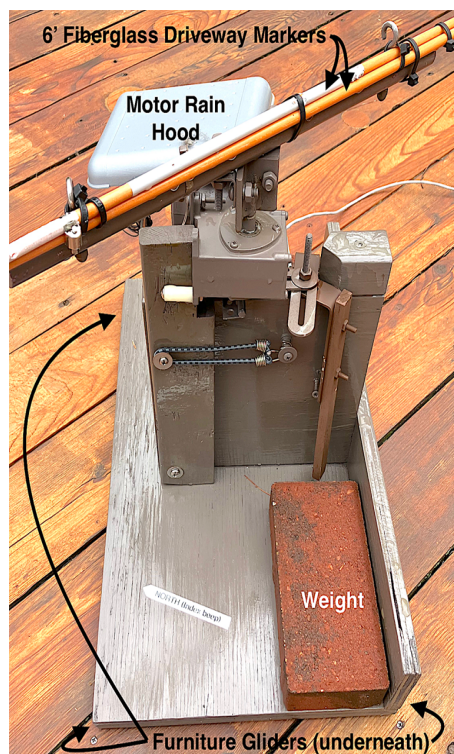
When the target frequency is approximately achieved, move *only* the shorting slider to deepen the minima. The direction of shorting slider movement needed cannot be predicted, so try ¼" to ½" and re-test. The center frequency will *drift slightly* (as illustrated by the blue arrows). The direction of drift will depend on whether you are increasing or decreasing the distance from the feedpoint slider. If the drift moves you farther from the center frequency than you prefer, move the Feedpoint Slider and the Shorting Slider by small, equal amounts to shift the entire curve slightly right or left.



## (22) The 'Marionette Drive' and Other Rotator Options:

2023-1212: There are many possible ways to rotate a Hen-Delta so feel free to use your imagination. Since the antenna is bidirectional, you only need to rotate it 180° –actually only about 160° is necessary since the azimuth beam is fairly wide. I built a homemade multi-360° geared motor 'Marionette Drive' from spare parts as shown in Chapter 5. But that degree of complexity isn't necessary and a simple 12V linear actuator is easier to work with, as illustrated on the next page. Linear actuators are available with different extend/retract speeds, so choose one with an appropriate speed – probably about 1-2 inches per second or it will take longer than you would prefer to slew the antenna. Most linear actuators have built-in limit switches to stop the travel when fully retracted or fully extended. The drive can be located directly below the antenna, or off to the side, depending on how it is built and connected. Conceivably the drive could be above the antenna, but then the 12V power wire might be in the way or affect the radiation pattern... unless a battery-operated remote control was used? There are endless possibilities. Keep in mind that the rotator is basically shortening one 1/8" Dacron cord while lengthening the other by the same amount, and there is no need to always connect to the top element's outermost ends – you might connect a foot or two from the center point of the top element, depending on drive location. A twisting rope support is practically a frictionless bearing. I would suggest some means of limiting the force on the J-hook and pulley in the event of an unexpected wind gust. My solution was to have my marionette drive's mounting platform rest on furniture gliders so that if the steering lines were excessively 'yanked' by the tree limb, the entire drive would slide across the deck and relieve the tension before any damage could be done. I found that adding two paver bricks on the drive's platform provided a good balance between stability and strain relief.

Using fiberglass 'driveway markers' to add a degree of flexibility to the marionette arm and maintaining a modest degree of line tension is a good idea, especially if your antenna is suspended in a tree and therefore subject to wind motion.



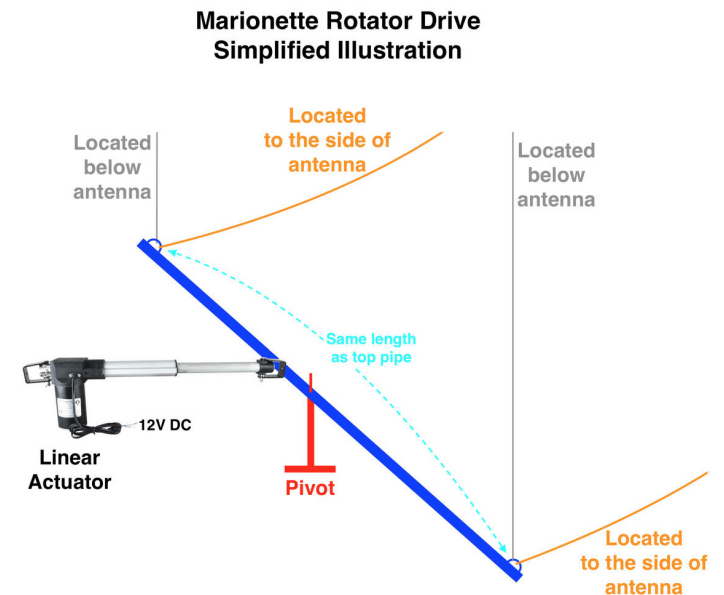
Rotator position feedback can be provided by:

- a) the drive having a very limited number of positions, such as two or three,
- b) from a magnetic on the drive shaft and magnetic switches above or below it,
- c) from a potentiometer at the pivot point,
- d) from a 12V RV backup camera with a monitor in the shack. This is what I use (see monitor image with added compass reticle in Chapter 10). You might choose between watching the marionette arm rotate, the linear actuator extend or retract, or look straight up at the antenna's top element from below. The camera lens is wide angle so the top element image will be small – about 1/2" on a 7" monitor. So a 1080P resolution is a good idea. Most RV backup cameras have a feature allowing you to reverse the left-right image, which is sometimes crucial when looking upward at an antenna. Some will also let you mount the monitor upside-down to minimize the bezel thickness where the switch row is, and flip or rotate that axis, too. Be sure to check on what image flipping and rotating options are available. I chose a Rohent\* R4 HD two-camera and 7" HD monitor system on Amazon. All such cameras have infrared LEDs for night vision. If needed, reflectors or reflective tape at the top element ends can let you see the position clearly at night. I used reflective tape and it is clearly visible.
- e) Something else.

\*Anecdote: One of my two camera's suffered from an odd 'foggy image' fault *after* the one year warranty expired, and I emailed the company asking where I might buy a replacement since I didn't see one offered on Amazon? They sent me a new camera free! Now *that's* good service! I dissected the failed camera and found the interior components were vacuum or pressure potted into a solid block of rubber, and there was no sign of moisture intrusion anywhere. I also found the smallest solenoid I have ever seen, which flips a tiny lever to move a tiny (3/8", 8mm) IR filter disk in front of, or clear of, the sensor's view. The 1" square board appears to be a 'system on a chip' with a tiny CPU and flash memory. My impression was that the camera was of a good quality design. The camera's sides have *brass* inserts for mounting to the tilt and rotate (alt-azimuth) mount. The cause of the 'foggy' image was never discovered.

Keep in mind that the marionette arm will stay roughly parallel to the top copper pipe element(s), so locate the linear actuator's attachment distance from the pivot point such that you can get nearly a full 180° of motion from one stop to the other (160°-170° is fine). The steering cords are tied to the antenna's top copper pipe at or near the pipe's ends (also see p71, 'Vertical') with plastic swivel snap hooks (3", 75mm, 'Blumoon' brand, Amazon; see collage on previous page). Take up excess cord slack near the marionette drive's fiberglass arms using taunt line hitches, which allows easy adjustment of line tension. If needed, an alligator clip on the steering line can prevent the hitch from slipping down the line. This 'steering cord' system allows you to deploy or park the Hen-Delta antenna as needed, and when parked the lines just go slack. Take care not to get the ropes and cords too tangled, though, as that can be a nuisance. For a *vertical* marionette drive see Chapter 23.

The linear actuator's (or motor's) direction of travel is determined by the polarity of the 12V DC applied to its two wires. A center-off DPDT switch is typically used to reverse the polarity and control the direction of the antenna's rotation.



## Rotation by Antenna Selection:

2023-1217: The intrepid amateur will quickly realize that a Marionette Drive system is a bit complicated and ‘messy’, especially if you wish to build a Vertically Mobile Antenna to optimize local-through-DX take-off angles (see Chapter 24 below). From personal experience it would be easier and far more robust to build two or three same-band Hen-Delta antennas than to build a reliable rotator. The only penalties being larger size, more weight, a switching mechanism or coax relays, and stealth.

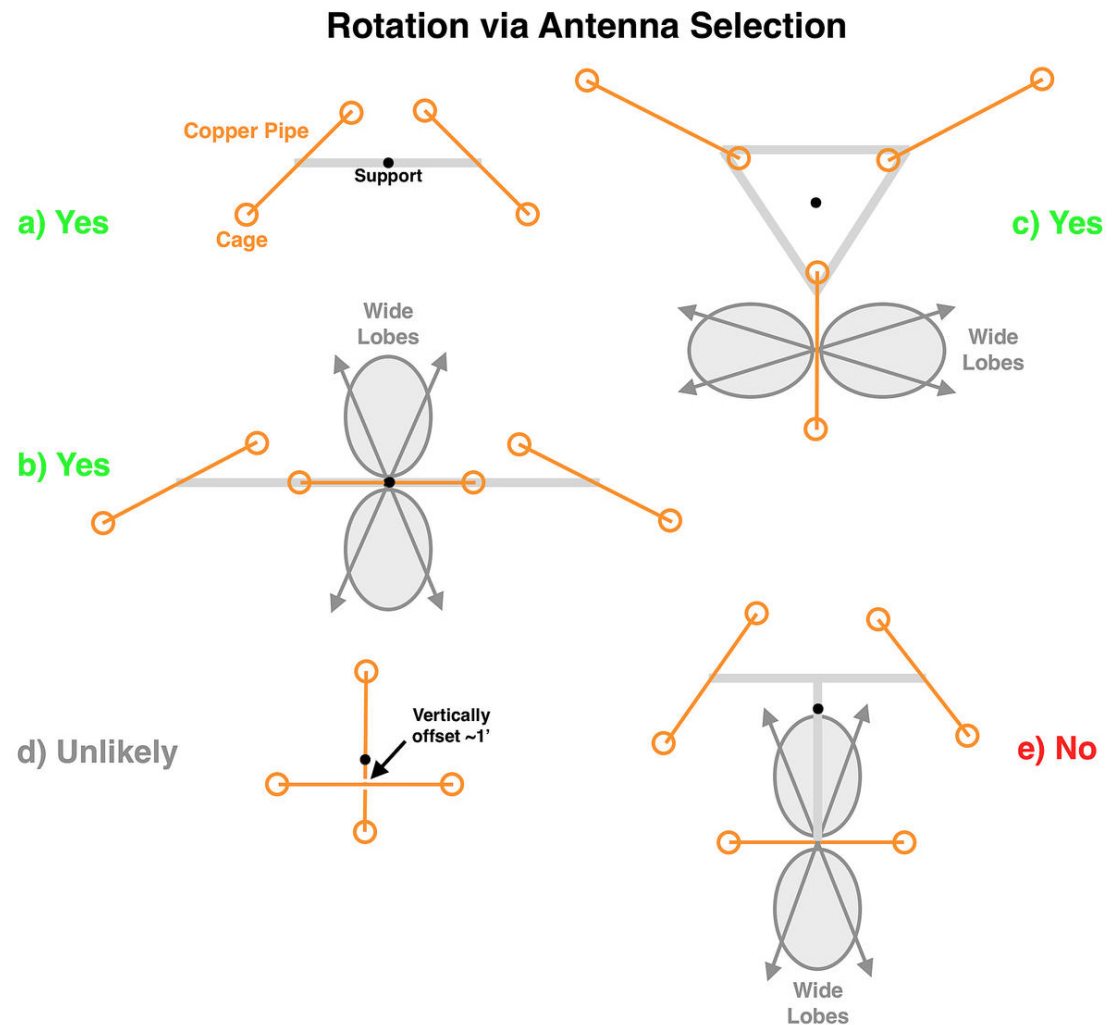
The key point to remember is that it is best to keep each antenna out of the other’s radiation pattern as much as possible since each Hen-Delta antenna is a *complete loop*, *whether fed (selected) or not*, and so tuned as to parasitically resonate with a nearby antenna’s transmission to the extent it is in the broad radiation pattern. Some possible geometries are shown at right.

Keep in mind this is *theoretical* – I have not built these! The antenna sets (a), (b), and (c), keep their neighboring antennas out of their patterns fairly well.

Antenna set (d) is compact and the two are at right angles to one another, but their large cages are directly in each other’s beam path. Note they are offset both vertically and horizontally, so that the tuning stubs don’t hang too near one another – they would also need to be secured to one another by a non-conductive mechanical means (fiberglass rod) to prevent pendulum sway of the tuning stubs.

Antenna set (e) would likely not work as the two non-selected antennas are both well within the selected antenna’s radiation pattern *and* resonant at the same frequency. Not good. Unless...

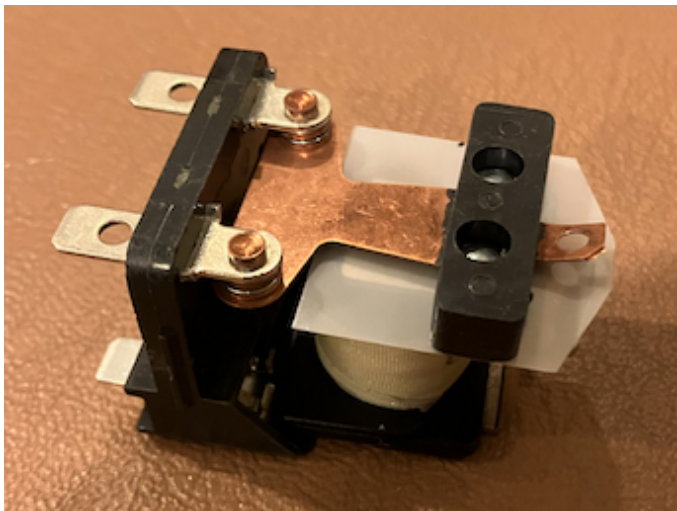
**Opening non-selected loop antennas:** It occurs to me that these pesky parasitic coupling issues would ‘disappear’ if *all non-selected loops could be ‘broken open’* by relays. A convenient place to locate a relay would be just above the tuning stub between the connection ‘pigtails’ where the vertical ‘down wire’ cage attaches. Thus opened, the proximate non-selected loops *no longer exist* and cannot ‘load’ (couple to) the radiated power of the nearby transmission. That might make (d) and (e) feasible if a compact geometry was crucial. It seems certain that there would be high voltage present on the contacts of a *single* opened relay when a nearby antenna was transmitting, *so two relays should be used, one at each of the tuning stub’s two top pigtails*. This would create two ‘**remnant wires**’ of the original Hen-Delta loop – now just two isolated ‘wires’ – one long, one short. Neither of their resonance frequencies would couple to the selected antenna’s **transmission frequency** – thus greatly reducing any voltage present on the contacts of both open relays. It’s an intriguing thought, although extra relays present their own issues of cost, wiring, and reliability.



The concept is worthy of its own (simplified) illustration, at right. Each of the two or three antennas has a ‘relay disconnect board’ (black rectangle) which must be strong enough to support the weight of the tuning stub, current balun, and other structural load impulses. It should have a rain hood of some kind, or be otherwise sealed to protect the relays. The two SPST relays will be powered at the same time and should ideally be of the ‘double break’ (NC) or ‘double make’ (NO) contact style (below). Normally closed (NC) is best so that a power supply fault or broken wire won’t leave all the antennas open, but normally open (NO) relays might be used with some kind of confirmation feedback signal – always a good idea if practical. The ‘selected’ antenna has unpowered NC relays and thus closed contacts, all of the others are powered and have open relay contacts. The relays must be rated to carry the full power applied to the antenna.

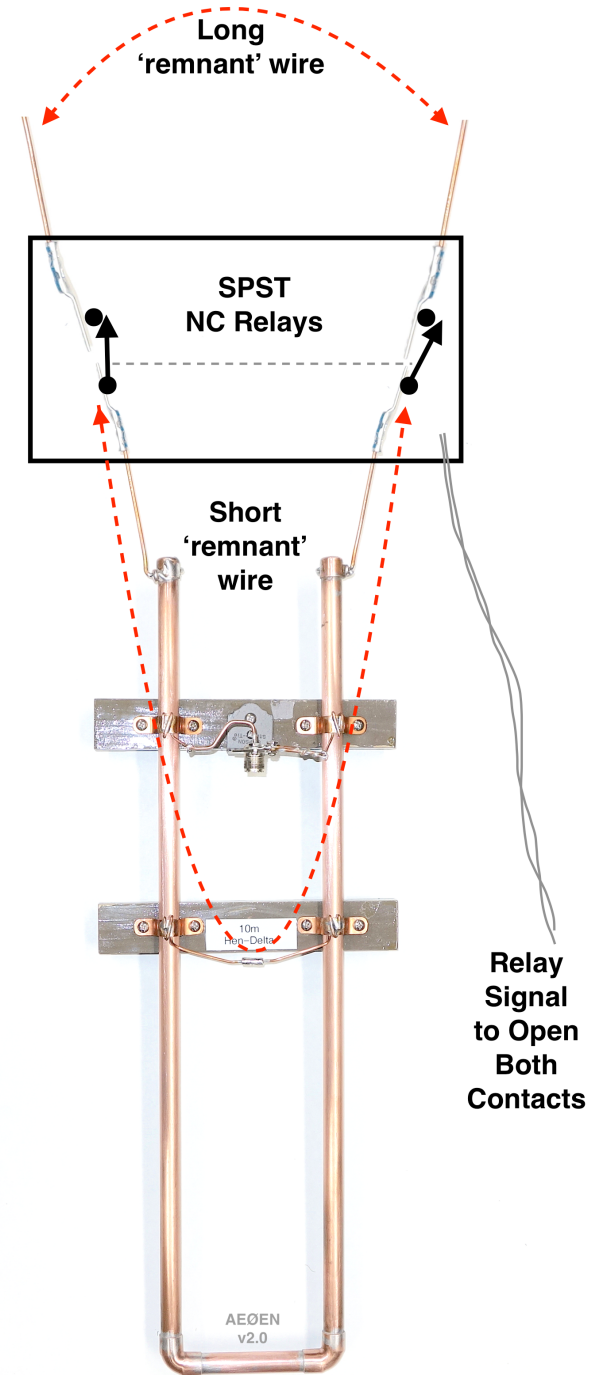
In this manner the open, *non-selected* antennas each exist only as two **remnant wires** (dashed red lines), a *long wire remnant* consisting of the Hen-Delta’s top element and the two caged ‘down wires’ that end at the relay disconnect board, and the *short wire remnant* which is the tuning stub, shorting slider, and the two pig-tails on top – typically at least 30” (0.75m) in length. Neither of these two remnant wires would be resonant near enough to the frequency of the selected, driven Hen-Delta loop, to couple efficiently with its transmitted RF, and thus neither relay would see much voltage induced on their open contacts.

Other consequences of this concept is that multi-band *collections* of Hen-Deltas (say, a 10m/12m/6mX2 and a 15m/17m/20m) could be fixed to the same very short 3’ boom and the non-selected antennas could be disconnected to minimize resonant interactions. This same versatility *could* be used to make a Hen-Delta *reflector element* ‘disappear’, returning the driven element to normal bidirectional operation. Related: Note that if the tuning stub were long enough to support 1.05 wavelengths (as a yagi reflector element does) then two such identically configured Hen-Deltas could swap being reflectors, allowing for 180° rotation rather than 360° rotation.



These relays replace the fixed shorting slider wires (right) on *multi-band* Hen-Deltas, excluding the bottom one. More on this later.

Left: 30A **double-break** relay (only the left two terminals would be used). Midland Ross 188-35B200 (shown) or nearly-identical 188-25B2U1 (from rfparts.com). Note the latter relay has two additional terminals which are not connected to anything, so it is functionally identical.



## Antenna Direction Monitoring via an Upward Looking RV Backup Camera:

2024-0802: The simple homemade ‘marionette drive’ that I use doesn’t easily lend itself to potentiometer feedback as a typical rotator would. After much thought, the lowest cost/maximum utility option was to use an inexpensive (under \$100) RV backup camera with HD resolution, and a 7” HD monitor – a decent size. The wide-angle nature of the ‘RV backup camera’ results in the top element of the Hen-Delta appearing rather small, but the HD resolution nevertheless makes its orientation very discernible.

Another advantage of directly viewing the antenna is that sometimes steering lines get snagged, catch on limbs, or the ‘marionette drive’ is pulled out of position by wind gusts. The drive sits on a weighted base on furniture gliders, so a wild tug on the steering lines isn’t catastrophic, the base just slides a few feet across the deck — a deliberate safety feature. But it also means a drive’s hypothetical feedback potentiometer might not have any idea which way the antenna is actually oriented. But if you can *see* the antenna you *know*!

During daytime the top element itself is visible, when *completely* dark the camera’s built-in IR LEDs combined with its ‘night mode’ make the reflector tape on the ends highly visible, and during twilight (just prior to ‘night mode’ activation) two bright white LEDs driven at 15mA illuminate the reflective tape when their momentary pushbutton is pressed. This same pushbutton serves double duty — along with a DPDT switch which reverses the polarity of power driving the LEDs *and* the 12V linear actuator’s motor (repurposed from a decommissioned antenna project). The LEDs are fed through a diode bridge so they illuminate irrespective of polarity. The linear actuator will retract or extend to the limit of travel in about six seconds and then stop itself, remaining in that position indefinitely until the polarity is reversed. Thus any further power supplied to the white LEDs/motor pair only illuminates the LEDs.

As you can see below, if the 1/4” plexiglass (acrylic) cover happens to be clean and not obscured by rain, snow, leaves, etc., it is possible to see antenna orientation *through it* during the daytime. Because plexiglass blocks IR from the camera’s LEDs, at night the cover must be retracted to see the reflective tape... at least long enough to check or reposition the antenna.

The first generation of camera mount had a manual cover which I often forgot to re-install at the end of a radio session. This subjected the RV camera to rain which pooled on the lens and over a year of alternately being baked by the sun and being rained on, the camera image became foggy although still usable. It’s a pretty hostile environment for an inexpensive camera (see ‘*\*Anecdote*’ three

pages above). The moving plexiglass cover is my second generation camera mount improvement, and should serve to protect the replacement camera from the worst of the weather.

The fixed castors supports may seem like overkill for 1/4” (6mm) thick plexiglass, but I have found all plexiglass to be too-often fragile or brittle, especially in cold weather. Lexan (polycarbonate, Amazon) is a much stronger material, so if the plexiglass fails I will use it next time. But Lexan does turn yellow when exposed to UV for long periods. Were Lexan to have been used initially, its strength would have allowed the outer (leftmost) two rollers to have been omitted.

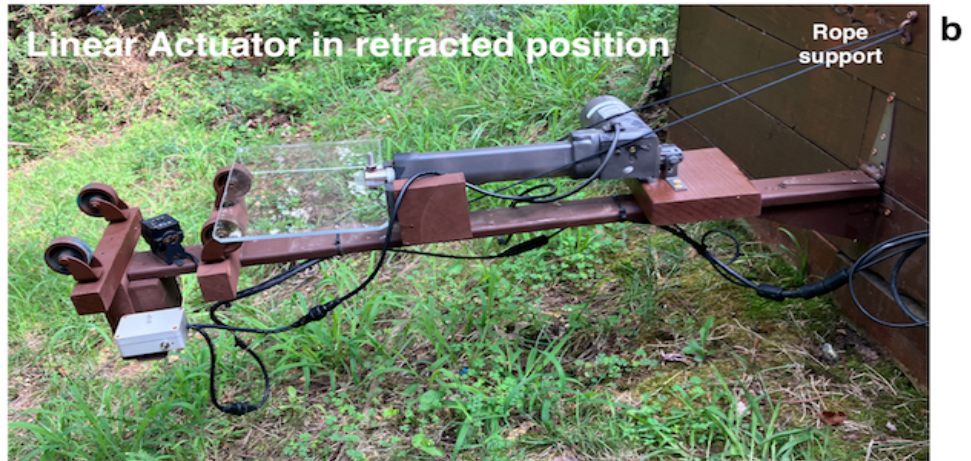
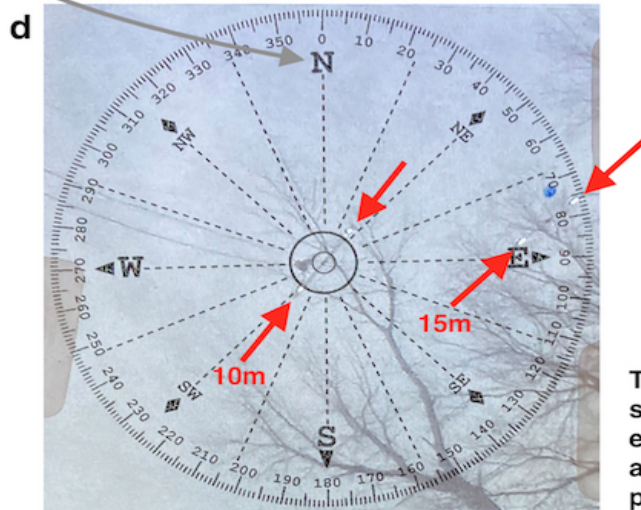
The rightmost castors are important because the linear actuator’s mechanical connection is via a coarse-threaded, single hole, slotted head which can and must spin freely – it does not lock in any position. When fully tightened the hole is at an awkward angle, so the head *must* to be free to spin such that it’s mounting slot is in a horizontal orientation. The inner two (rightmost) casters prevent the uncontrolled tilting of the free-spinning head and its attached plexiglass cover. The leftmost two casters provide support for the otherwise highly cantilevered cover when it is extended, eliminating the possibility of excessive stress at the vulnerable plexiglass-to-linear actuator connection point (the slotted head). While birds landing on an unsupported extended cover wouldn’t be a problem, a heavy snow and ice load might be, and squirrels leaping from nearby perches certainly *would* be – another argument for the future use of Lexan.

# Antenna Direction Monitoring via Upward Looking RV Backup Camera

Fixed castors support 1/4" plexiglass both when extended and retracted



White LEDs to momentarily illuminate reflectors during twilight when IR mode has not yet activated



Cable runs have not been tied up yet in these photos.

This winter twilight closeup of the monitor screen shows both the top elements and end reflector tape (red arrows) of the 10m and 15m Hen-Delta antennas. Lobes are perpendicular to the top element.

You can see the monitor's location in the 'Shack' here...

You might observe that the monitor (a Rohent model R4 from Amazon) is installed *upside down*! This was done to minimize the total bezel thickness between the radio's display and the monitor's display for video recording of both screens when occasionally testing an antenna's directional gain (see Chapter 10). The monitor's setup menu offers image rotation, left-right mirroring and up-down mirroring. Not all RV backup cameras offer so many options.

The compass rose reticle was found online, edited for improved clarity, then printed on 'Uinkit Inkjet Transparency Film' (Amazon) with my Epson inkjet printer. The results were quite good. The reticle is held on the screen with four removable Post-It bookmark tabs, which you can just see at the edges. This allows me to occasionally re-center the compass reticle's position for best alignment.

The camera need *not* be perfectly located directly below the antenna to perform well, as you can see with the 15m antenna at the East edge of the monitor's screen on the previous page.



## Antenna Surge Protection:

2024-0713: All of my antennas – loops and Hen-Deltas – are protected with Paradan Antenna Disconnectors. For the two Hen-Deltas (10m/12m and 15m at present) I use their *Dual* Antenna Disconnecter. Here is a snip from the product web site:

*“The Dual Antenna Disconnecter automatically disconnects two antennas from your radio and grounds both antennas. The Disconnecter prevents static-discharge, surges, and lightning-strike effects from damaging your radio and associated equipment. When the transceiver [or its power] is turned OFF, the antennas’ signal and ground wires are shorted together and grounded, and both the coax centers and coax shields are disconnected from the radio. When the transceiver is powered ON, the Disconnecter re-connects both antennas for normal operating. Power for the Disconnecter comes from the transceiver’s auxiliary power socket, or connect it to your power supply that you turn off when not operating.”*

For my Paradan I created this vented, weatherproof shelter using a spare waste basket. The top, far edge of the trash can is vented behind the vent’s rain shield – a gray angle aluminum ‘L’ – so that the summer sun doesn’t transform the container into an oven – the hot air vents out the top. Cool air enters at the bottom, and coax cables to the Hen-Deltas also exit from the bottom. The 2x4 on top prevents the container from being blown away by storm winds (so far) yet it can swing up out of the way so



I can lift the container off the Paradan and have access to the connections if needed.

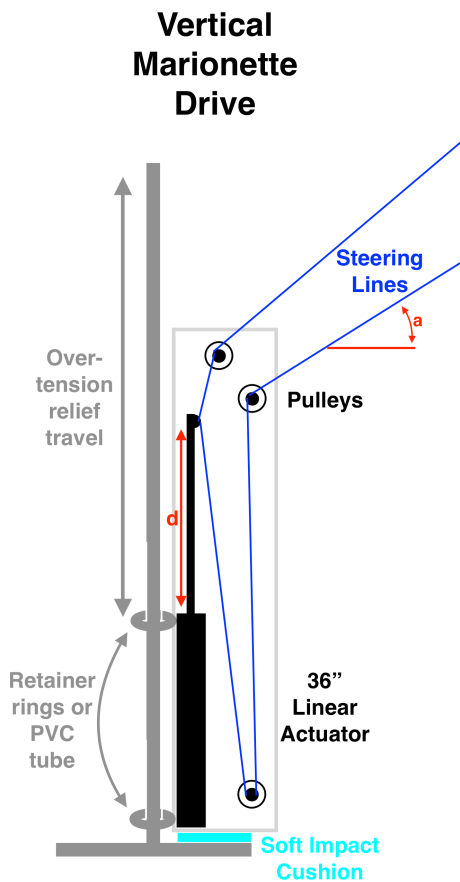
I continue to manually disconnect the two coax PL-259 connectors from the tuner if storms occur or are forecast, but its reassuring to know the radio is well protected if I forget or if I am away at the time.

## (23) Future Concepts:

### Remote Stub-Tuning:

2023-1227: (Right) By reversing the mounting of one of the tuning sliders it becomes easier to mount two weather-proof Linear Actuators to ‘live-adjust’ the positions of the tuning sliders independently. This isn't necessary for the vast majority of sites, but in the case where a ‘vertically mobile’ Hen-Delta antenna was desired (see Chapter 24 below), or considerable experimentation expected, remote tuning might be an interesting option. Note that *multiple feed-point and shorting sliders* could also be utilized and might be simpler to construct (see Chapter 6). It might also be that only one Linear Actuator – for the shorting slider – would be sufficient if there were multiple feedpoint sliders to choose from?

If two Linear Actuators are used they need to be to be the same model so that their extend/retract speed is the same. For frequency centering both motors are run at the same time and in the same direction (extend = upward = higher frequency) to maintain the same slider separation distance. Then the shorting slider motor is run to lower the SWR minima to as near SWR 1.0 as is deemed appropriate.

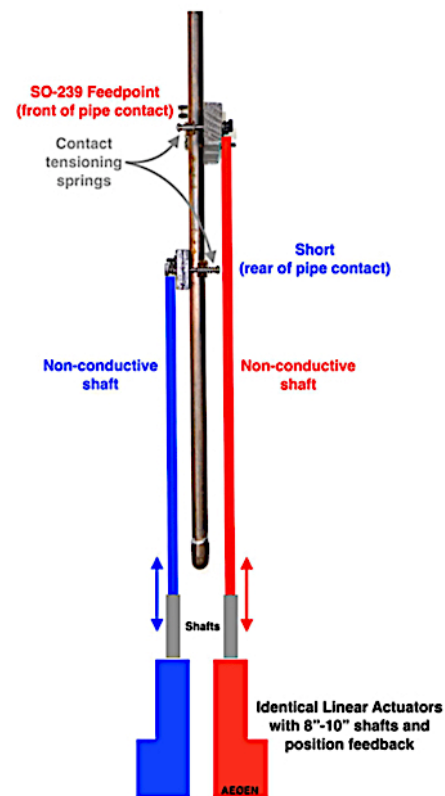


It might be possible to automate the tuning vs height above ground with a table in a computer to control the linear actuators. For this to work there would need to be an accurate position feedback potentiometer. Some linear actuators offer this feature.

### Vertical Marionette Drive:

2024-0701: (Left) Any means of extending *and* retracting the *steering lines* will rotate the antenna *unless* the rotator is directly *below* the antenna. This ‘small footprint’ vertical Marionette Drive concept uses a long, fast ~36” linear actuator to pull in one line while letting out the other. The steering lines would need to be attached about  $\pm(d/2)/\cos(a)$  from the center of the Hen-Delta’s top element (example:  $(36''/2)/\cos(45^\circ) = \pm 25''$ ), and should provide  $\pm 85^\circ$  of antenna rotation, which is plenty given the azimuth beam width. The retainer rings (gray) will allow strong wind gusts to lift the entire drive on its vertical mounting post to reduce excessive steering line tension. A soft base cushions the drop impact, if any. A tether line, not shown, could allow the drive to be completely lifted off its mounting post during extreme gusts, yet not crash to the ground. The mounting post and drive may also be installed at *any desired angle*, such as tilted  $45^\circ$  toward the antenna, or even horizontally – but if gravity will not suffice to return the drive to its lower ‘home position’ some other mechanism will need to do so, such as a tensioning weight hanging from a pulley. Rotating two or more antennas is possible with additional pulleys to manage the lines. Small weights hung 6’ out on the steering lines might serve to equalize line tension. One nice aspect of using linear actuators is that you can’t inadvertently cross the steering lines, which has happened to me when I lose track of where my rotator’s extension arms are. There must be *dozens* of ways to rotate a lightweight antenna without using conductive materials – be creative! For example, a large plastic spool with a gentle bungee cord as a mainspring (anchored to a fixed object) could reduce the marionette drive to a single rope. Pull in for clockwise, let out for counter-clockwise.

### ‘Remotely Tuned Stub’ Concept (Side view)



## ABS Pipe Mast:

Where tree mounting isn't practical or desired, it *may* be that a simple mast of two nesting 20' ABS pipes might be used to support the 10-15 lbs of weight of a Hen-Delta. In the table of pipe sizes (right) it is evident that either 2" & 2.5" (blue arrow) or 3" & 3.5" (green arrow) pipes have dimensions suitable for the overlapped (nesting) of their joints with fairly tight interior clearances of 0.070" and 0.021" respectively. I have no idea how much variance there might be in either the outer or inner dimensions, and it might be that some individual pipes nest perfectly and others do not, but it seems likely that most would nest.

(Note that **Schedule 80** ABS pipe, with *thicker walls* than Schedule 40, only nests at one size pair: 1.5" and 2", with 0.013" of clearance. I have no idea if this diameter would be strong enough for a mast.)

If the ABS pipe as illustrated – much stronger than PVC – is still too weak, nesting almost two full-length pipes to *double the wall thickness* of the *lower* pipe might stiffen that section of the mast significantly, but with additional weight and cost.

The three guy lines need to attach to a point *below* where the tuning stub would be. Because the mast pipe itself need rotate only  $\sim 170^\circ$  (about  $\pm 85^\circ$ ) to complete bidirectional coverage, the slip ring shown (a piece of ABS cut from the larger pipe) may not be needed at all – the guy ropes will simply tension by 'an inch' more or less as they rotate  $\pm 85^\circ$  with the pipe, so keep guy eyebolts short or use padeyes. Eliminating the slip ring simplifies the design considerably.

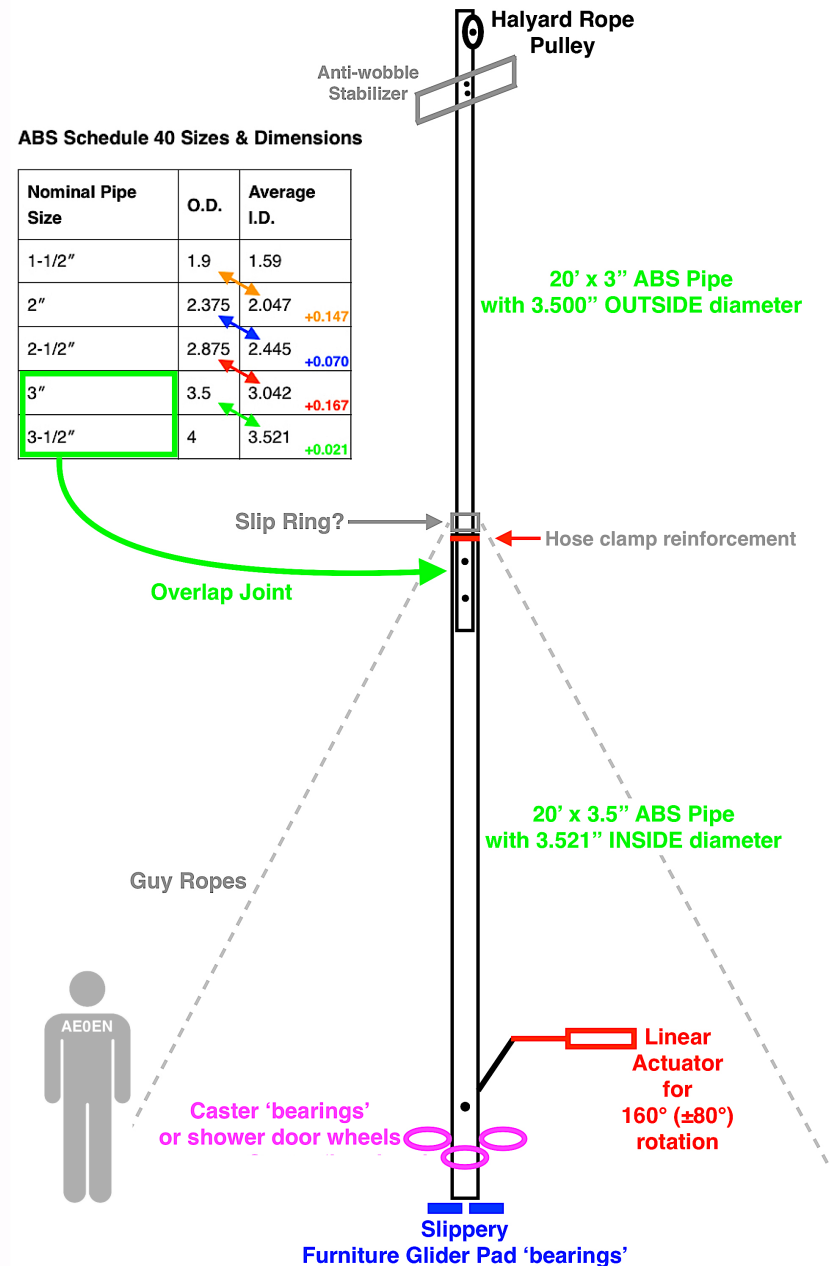
On the illustration at right, by 'caster bearings' I am referring to 'furniture casters' (wheels) of the fixed-mount variety. These securely keep the bottom of the pipe in position but allow it to rotate easily. These should be weatherproof stainless steel or brass. A dozen small shower door rollers might be strong enough – glass shower doors are *heavy*.

The non-conducting 'anti-wobble stabilizer' at the top exists to prevent the Hen-Delta from twisting in the wind around the pipe – like a flag might – and to keep it oriented correctly. It should securely engage the copper pipe, perhaps in an inverted, padded U-channel.

The top rim of the lower pipe (just below the 'slip ring') should be reinforced with a stainless steel hose clamp or equivalent (see small red line). The pipe rim is the most likely stress-failure point in the structure.

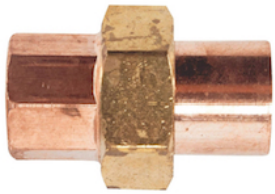
This is a *concept sketch only*, so an actual tower would likely need several design improvements. Also see Appendix 4.

## 38' Hen-Delta Mast of Nesting ABS Pipe Concept



## Transportability:

The Hen-Delta antenna, while not exactly ‘portable’, might be deemed lightweight and collapsible enough to be ‘transportable’ if the top element’s copper pipe length can be reduced through the installation of one or more ½” **copper-to-copper** unions (copper, *not* brass or bronze). The installation of one union would reduce the top element’s length by half, and two unions to a third. The threaded brass ring forcefully compresses the two soldered (sweated) copper fittings together in a broad face-to-face design which should make an excellent, low resistance connection. Installing unions requires that the support ropes are tied near the pipe ends as shown in Chapter 20. A snug connection would require two wrenches for assembly or disassembly. ½” copper-to-copper unions are available on Amazon for less than \$10 as this is written. Note that I have *not* attempted this as yet as I have had no need to transport a Hen-Delta, but it

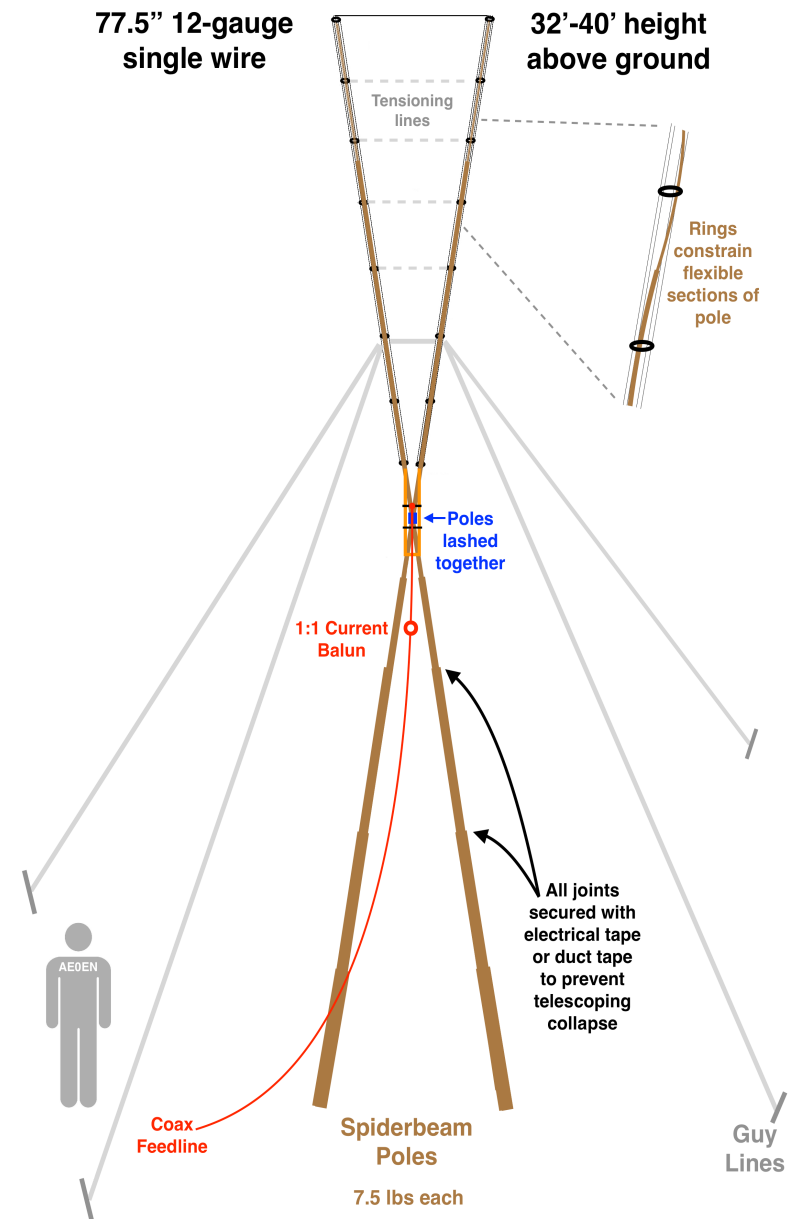


should work well.

## ‘DXpedition’ Spiderbeam Pole Hen-Delta:

Another Hen-Delta *concept* which I feel is interesting and achievable utilizes two 32’-40’ fiberglass Spiderbeam (or other) poles *within* the caged ‘down wires’ of the Hen-Delta as a form of *internal skeleton*. A 15m version is shown at right on two 40’, 12m HD model poles, but other band antennas should work fine *so long as the height above ground in wavelengths is satisfactory*. Spiderbeam also makes 60’, 72’, and 85’ poles (see link at right), although several of their thinner, weaker top sections would have to be omitted. **The cage rings would – to a degree – constrain and limit the bending the flexible uppermost sections of the poles, and the poles would support the weight of the antenna.** The heavy top copper pipe element would be replaced by a single 12-gauge wire to reduce the weight carried by the thinner upper pole sections, perhaps with a lightweight rigid structural element made from fiberglass tent poles or wood dowels. From my experience, an 8-section 32’ pole *should* be strong enough so as not to bend or twist excessively. A 9-tube 36’ or even the full 10-tube 40’ pole would have to be built and tested to find out – and guy lines near the top might be needed in some cases. A lightweight 1:1 current balun rated for the power to be transmitted should be attached near the feedpoint. Guy lines would be helpful to raise and lower the fully assembled structure of 20-25 lbs (~10 kg), and to stabilize the structure in use. A more complicated guy line design than shown here might allow one pole to be manually lifted and moved, or both poles to be manually rotated on a central pivoting 2x4, to orient the antenna as desired. The guy lines might even be attached to a large ‘slip ring’ on the antenna such that the poles rotate inside that ring. ***Much experimentation is needed***, and I only suggest keeping the top element and side wires as lightweight as possible – perhaps 4 or 6 wires of 16- or 18-gauge, with rings spaced to constrain the bending of tubes of the uppermost sections.

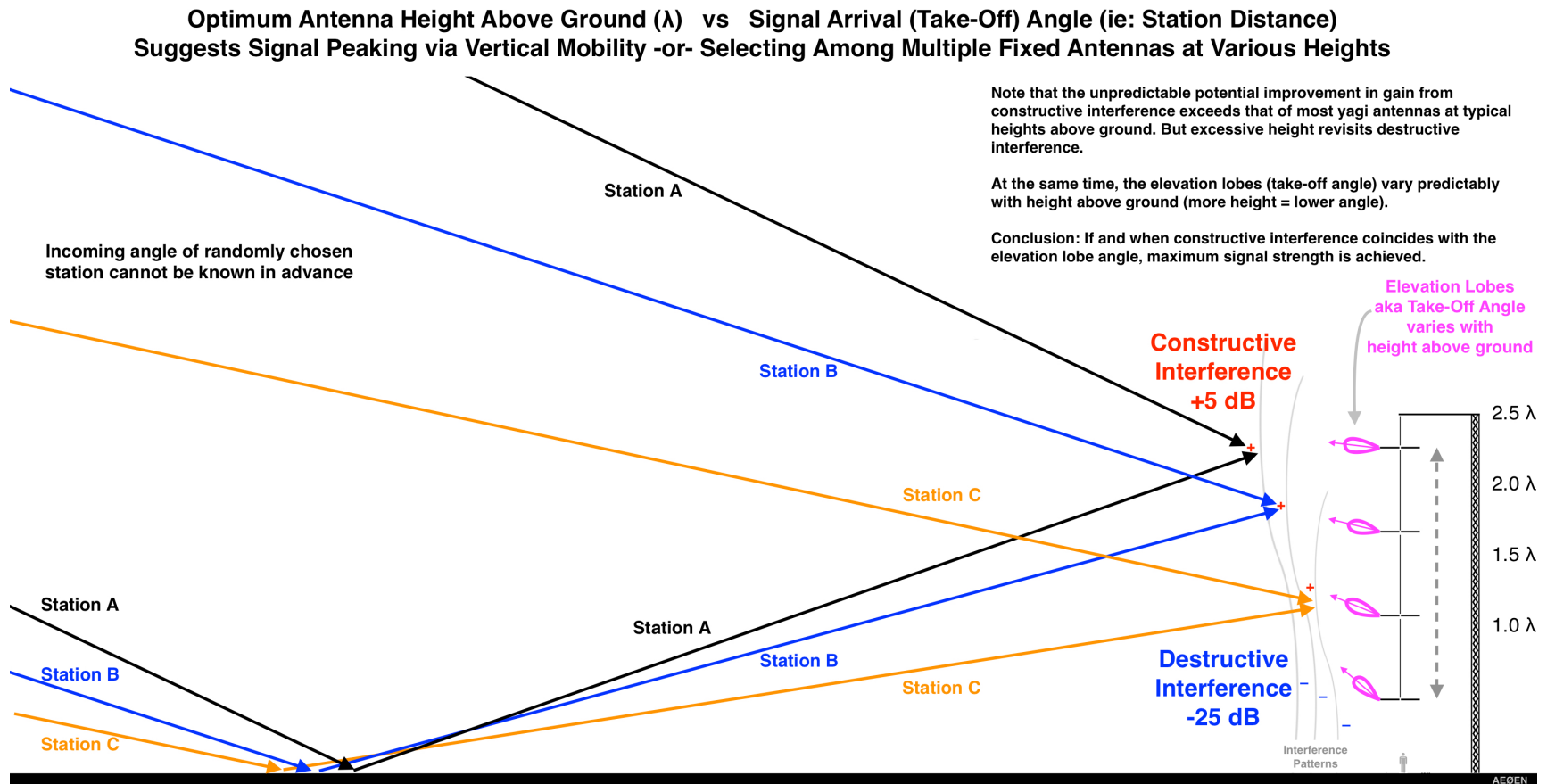
## 15m Caged Hen-Delta on Spiderbeam Poles



## (24) Optimum Antenna Height Above Ground:

2023-0810: While searching for some information on the ‘radius of effect’ for antenna height above ground I ran across this interesting article by K. Siwiak, KE4PT: [https://www.arrl.org/files/file/QEX\\_Next\\_Issue/May-Jun\\_2011/QEX\\_5\\_11\\_Siwiak.pdf](https://www.arrl.org/files/file/QEX_Next_Issue/May-Jun_2011/QEX_5_11_Siwiak.pdf) I found Figure 7 of special interest, but note that in my opinion there is an errata – the ‘data dot’ at height=5m should be at height=32m on the T=15° curve, vertically clustered with the other dots at 32m.)

Siwiak addresses the question of *optimum antenna height vs constructive and destructive interference of arriving signals*. With reciprocity it applies to transmitted signals. My take-away from the article (summarized in my illustration below) is the hypothetical desirability of a *vertically mobile antenna* which could be raised and lowered quickly to ‘peak’ a given signal. Alternatively, one could use multiple fixed antennas at various heights and then *select* whichever antenna has the strongest signal. Neither approach may be very practical, but **the astonishing point is that antenna gain from median to best height (about +15 dB) far exceeds that of a typical yagi at typical heights. The ‘overall best height’ is about 1.5 wavelengths**, with some signals *unpredictably* stronger nearer 1 or 2.5 wavelengths above ground (so higher may *not always* be better), depending on the signal’s unpredictable arrival angle AND the antenna’s predictable elevation lobe. The magnitude of gain is such that amateurs might seek out naturally occurring topographies of the appropriate height – such as bluffs, cliffs, and modest hills.



## (25) Trees as Antenna Supports (J-Hooks, Pulleys, Swivels, Shackles):

2023-0626: Trees and tree limbs are both a joy and a curse, and I have spent endless hours planning and implementing tree-supported antenna wires for loops and other antennas. Here are some techniques you might find useful, and some general tips:

1) Do your best to stay away from the upper tree canopy and any limbs that sway wildly in high wind as they will ensnare and entangle your wires every time. Try to find an open area of large limbs below the leaf canopy – like under an umbrella.

2) Tree movement sometimes requires a tensioning system to prevent the antenna wire from breaking. A plastic bottle (like a large vitamin bottle) partly filled with pea gravel and mounted via a pulley will work as a 3lb-5lb weight (see item #7 on this page). You can also add a weight at the end of a halyard loop which requires three pulleys (or more) – one on the weight and two ‘overhead’ to guide the halyard loop down to and up from the weight’s pulley. In this manner the entire halyard loop can move up and down on the weight, maintaining the same tension, but you can still pull either side of the halyard loop to change antenna tension or position.

3) Slingshots are fairly accurate (with practice) and can make long-distance shots, but the fishing weights often wrap around limbs to the point you have no choice but to break the fishing line in order to try again. That’s why I suggest line not stronger than 15 lb. To break the line wrap it around a heavy dowel a couple of dozen times and pull until it breaks. If the weight is too light it won’t pull the line down through the trees due to friction. 1.5 ounces is the minimum for one line, but sometimes 2 ounces is needed. If you spray silicon lube directly on the fishing line reel before starting, it can help reduce friction on the line as it drops through thick tree foliage and over bark. On a few occasions I have had to wait overnight for a perfectly-placed weight to slowly descend through a tree to the ground.

4) I use 3/8” aluminum for my J-Hooks (see below) because it is lightweight, strong (>150 lbs), and corrosion resistant. I paint it, of course.

5) If you have a very long telescoping pole (like a pruning pole or a portion of a spare Spiderbeam pole) you can sometimes *place* a J-Hook exactly where you want it in the fork of a tree limb using a 50-75 lb magnet on the pole and a small steel plate bolted a few inches from the pulley end of the J-Hook – this can make the J-Hook retrievable using the same pole and magnet. Choose a lo-

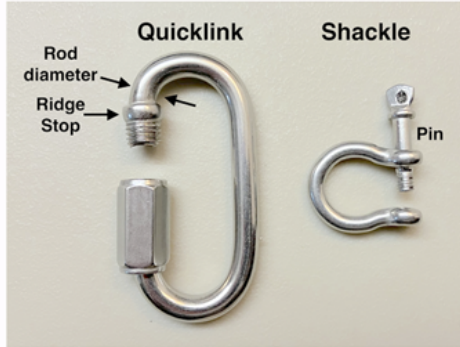
cation on a limb such that the J-Hook will not slide off the end of the limb – it should be blocked by a significant bifurcation. Try to size your J-Hook so that isn’t too much larger in diameter than the target limb. Having two people to manage the pole is often necessary at more than 16 feet – I’ve managed 25 feet that way using five sections of magnesium concrete pole extensions. These are *extremely* lightweight but *very expensive* – but then so are arborists – and mine have paid for themselves in tree trimming work several times over, just by mounting a removable tree saw blade on the far end. **Caution! Magnesium poles are *conductive* so *Do Not Use near overhead power lines*.** All of our utilities here are underground, so this isn’t an issue.

6) Take care in the selection of materials for your J-hook’s pulley attachment and remember that *for Hen-Delta supports, the downward force on the pulley, J-hook, and limb can be twice that of the antenna weight, depending on rope angle*. I have successfully used tie-wraps for low-load needs, but I have also had tie-wraps in other situations break for no obvious reason. Consider doubling up on them. As an alternative, consider using 10-gauge solid copper wire which you twist and solder into a loop (red lines, lower right). If you are running high power and want extra insulation between the J-Hook and the antenna wire, consider adding the appropriate length of insulating Dacron cord, heavy plastic chain, or a length of fiberglass pole?

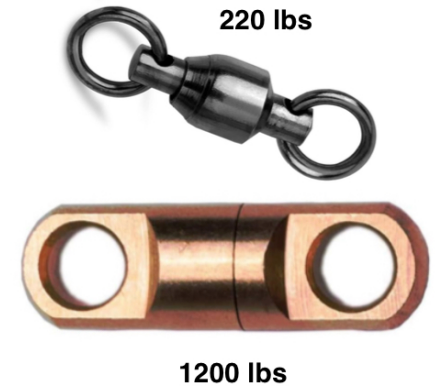
7) I have used a dozen of these small, tough, inexpensive plastic ‘kayak pulleys’ for years (Amazon, ~\$14 per pair). Note that the wheel (sheave)-to-sideplate clearance is *so small that no antenna wire can get caught between them!* It can be fully opened at the narrow end *only*. Do *not* remove the stainless steel bolt from the pulley wheel or all of the Delrin-like ball bearings will fall out (guess how I know that), however you *may* loosen it a half-turn to make it easier for the pulley sideplates to pivot open and be placed around a pre-existing antenna wire. If you prefer a higher capacity pulley, consider a stainless-steel sailing block (below, Amazon) of an appropriate size, but be aware most of these will not open. Most are also conductive and you would not wish a full ring of conductive material around an antenna wire. But as a rope support, pulley conductivity is not as issue. Any pulley can be spray painted for stealth.



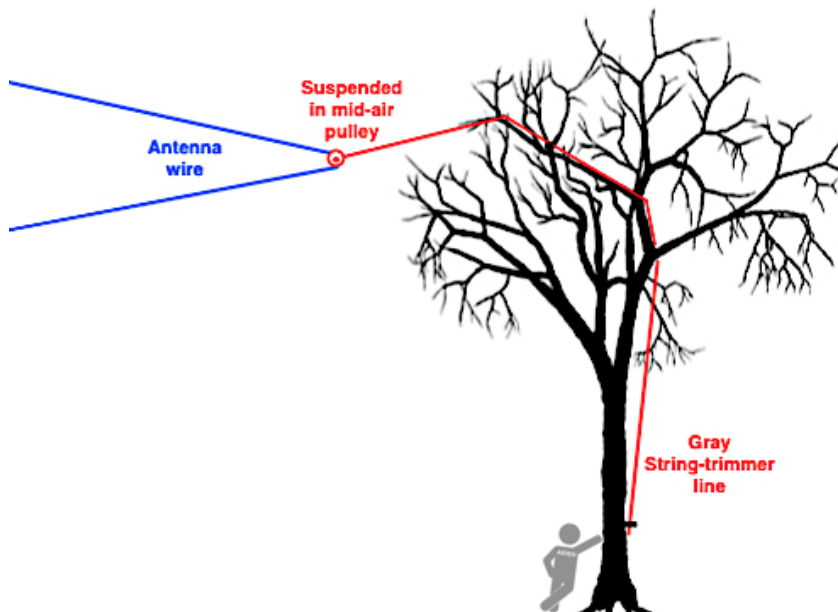
8) Attaching 220 lb stainless-steel, seawater-rated, fishing swivels on my non-swiveling kayak pulleys (see red lines on previous illustration) has been very useful because it helps keep the various wires and supports from twisting into high-friction tangles. Just tie-wrap (zip-tie) them or wire them under the small pulley's top bolt pin. You can find 1200lb salt-water swivels if you want them for a main rope support pulley – they are much lower friction than the swivels on the pulleys themselves. Both are on Amazon.



You may also wish some stainless shackles and quick-links (left) to interconnect parts. Shackles have the unique quality that their pin diameter will fit through a hole of the same size. On the other hand, a quick-link has a 'ridge stop' (my term) for its captive nut which is larger than the link's rod diameter. So while a 1/4" (6mm) *shackle's* pin can fit through a 1/4" (6mm) hole, a 1/4" *quick-link* may require a 5/16" (8mm) hole because of the ridge stop's larger diameter. This can be important if you are looking for a shackle or quick-link for a *swivel's mounting hole*. Thread-lock is recommended either way, but especially for the shackle. You may also 'seize' – tie closed – a shackle pin's *head* with a small tie-wrap (zip-tie) or with a piece of copper wire to prevent the pin from ever turning and falling out. Flat spray paint makes them stealthy.



9) On a couple of occasions where a 'suspended-in-mid-air' pulley's support line (see tree below) was subject to wear and tear from endless tree movement, I chose gray Husqvarne 'Titanium Force' 0.095" (UPC 93028 00976) string-trimmer line because it was both heavy line and had a fairly smooth surface – so as not to cut into the tree's bark over time. It is amazingly tough and abrasion-resistant material and takes spray paint well. Mine was up longer than a year (and through a cold midwestern winter), outlasting the main antenna wire it was supporting, which broke in a storm due to having become increasingly entangled in the tree canopy some distance away. Use a slingshot messenger line to create the desired path through the tree. To form a string-trimmer line *end loop* for the pulley, run it in and out of *uncrimped* barrel crimp connector, then apply epoxy near the barrel connector and slide- and-spin the barrel connector over the epoxy. Add more epoxy over all of it. But don't 'crimp' it – as that would deform and weaken the plastic trimmer string. You may add a second such barrel connector epoxied on the loose 'tail' of the loop as backup insurance, but I didn't experience a single failure with mine.



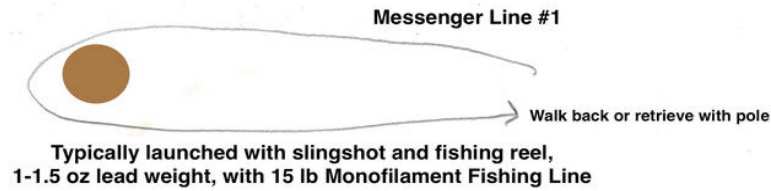
mer line *end loop* for the pulley, run it in and out of *uncrimped* barrel crimp connector, then apply epoxy near the barrel connector and slide- and-spin the barrel connector over the epoxy. Add more epoxy over all of it. But don't 'crimp' it – as that would deform and weaken the plastic trimmer string. You may add a second such barrel connector epoxied on the loose 'tail' of the loop as backup insurance, but I didn't experience a single failure with mine.

The following three pages summarize techniques in getting J-hook supports onto tree branches...

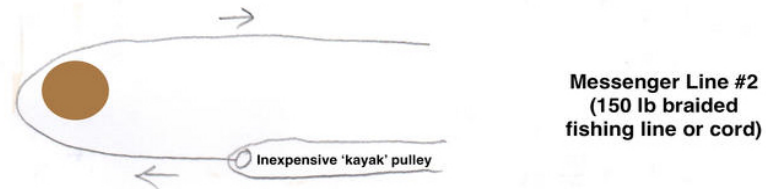


## USING J-HOOKS AND TREE LIMBS AS ANTENNA SUPPORTS, VERSION 1

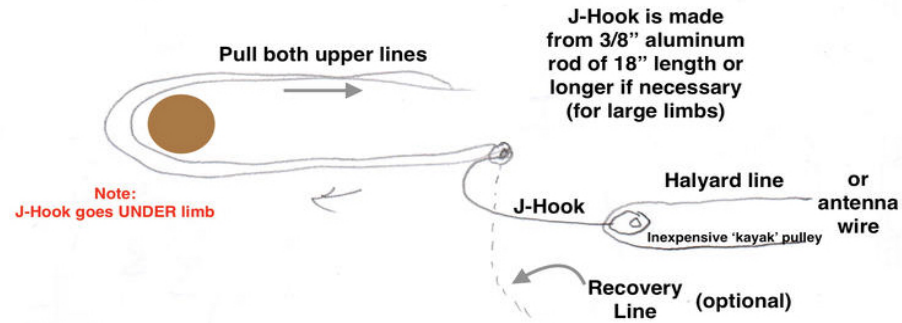
1)



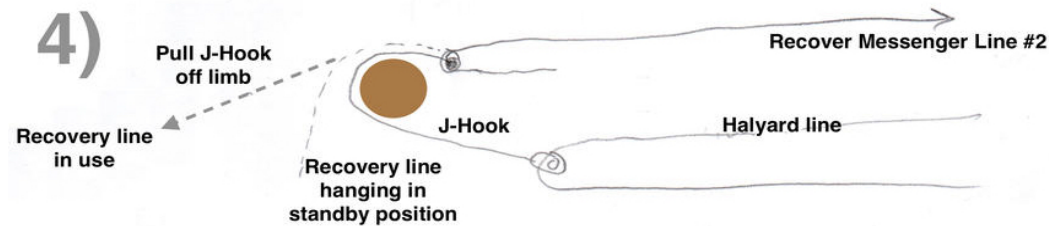
2)



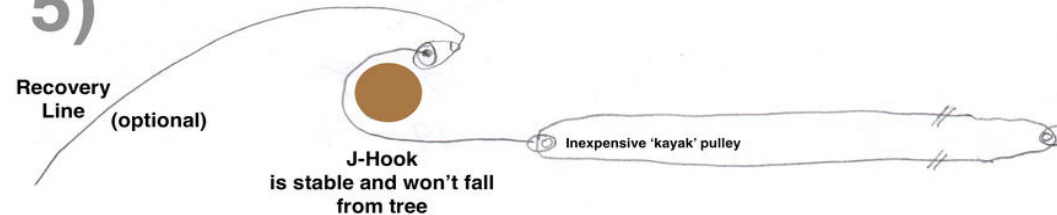
3)



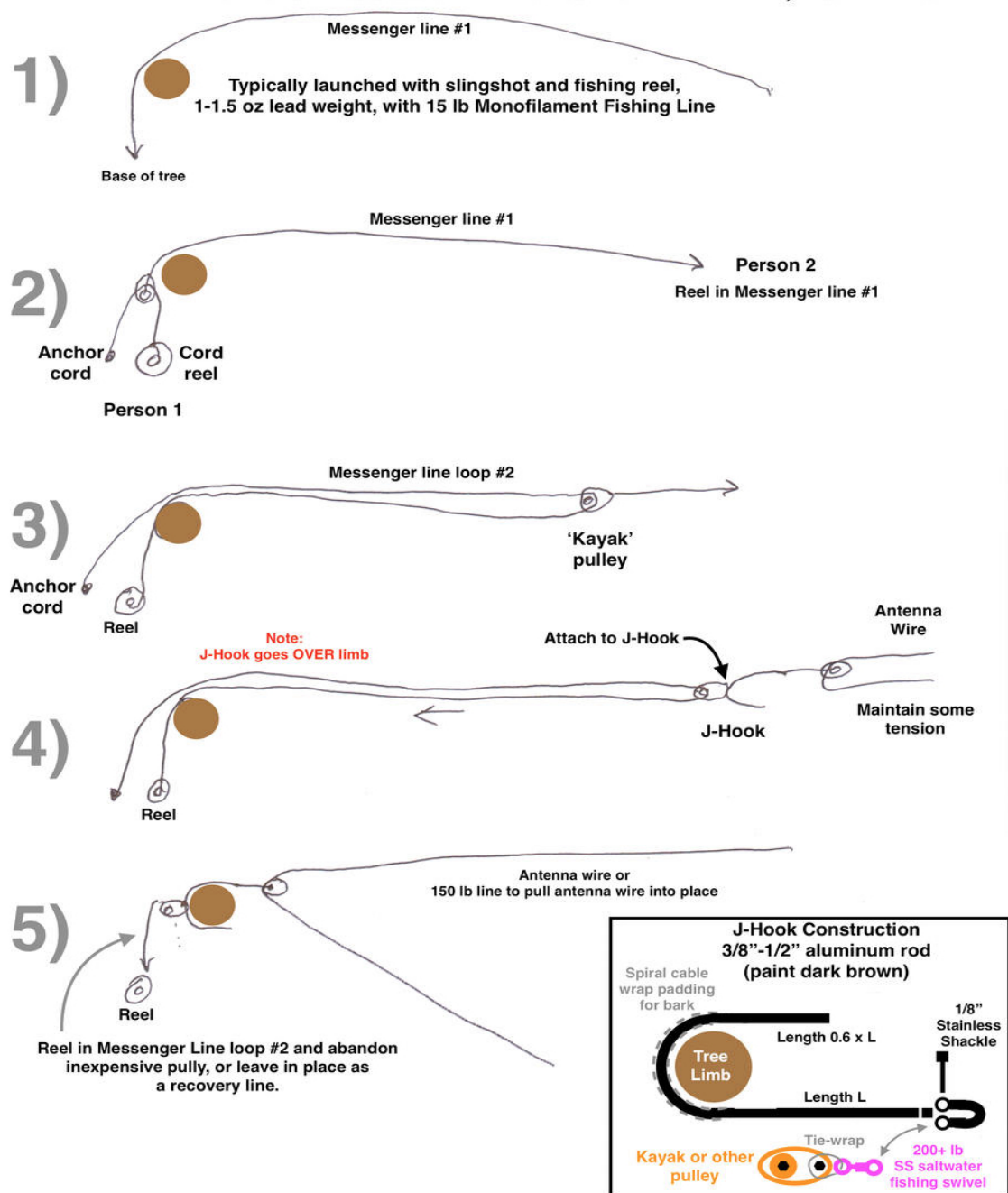
4)



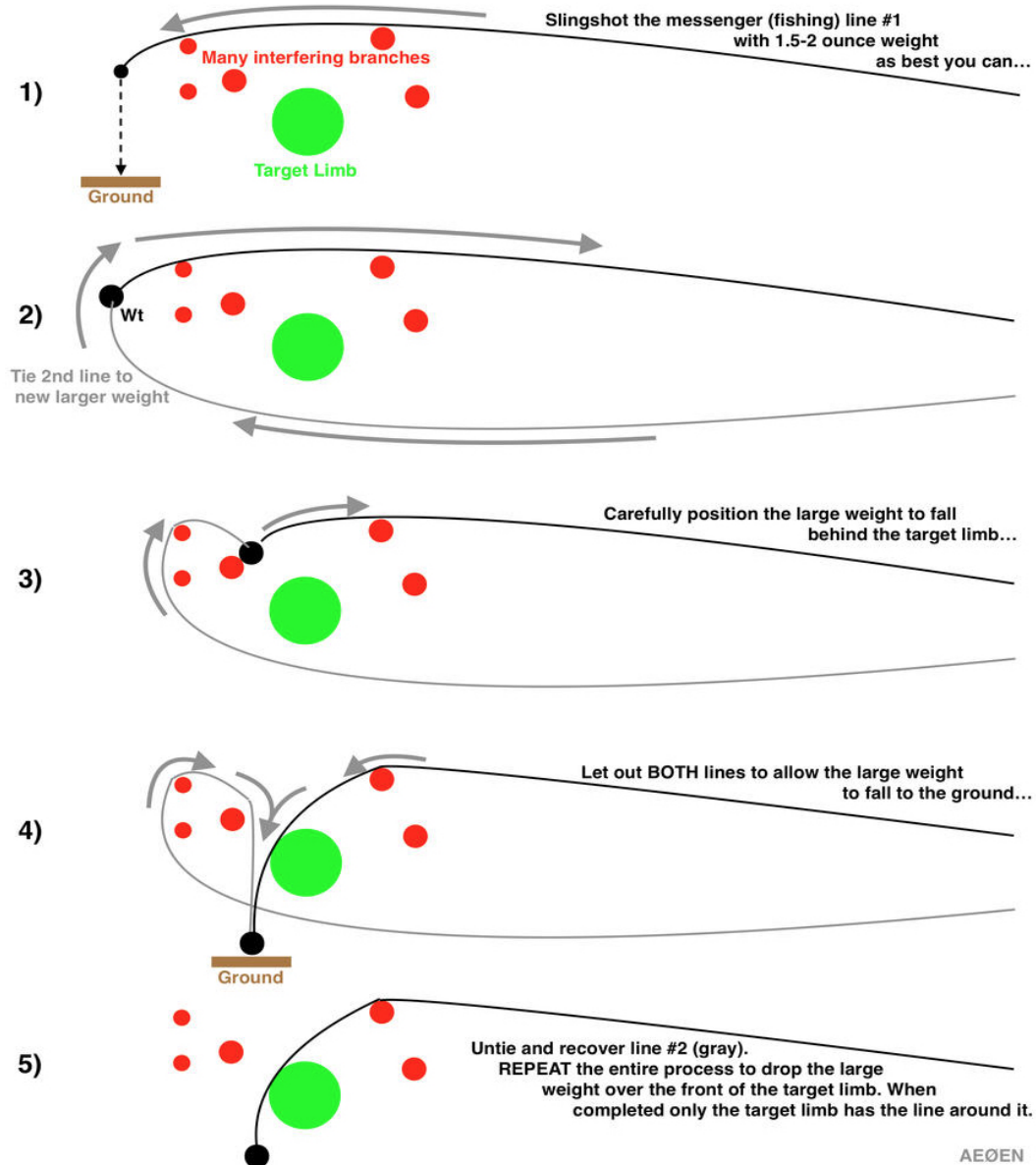
5)



## USING J-HOOKS AND TREE LIMBS AS ANTENNA SUPPORTS, VERSION 2



## Solving Complex Branch Interference When Preparing to Position a J-hook Halyard Pulley



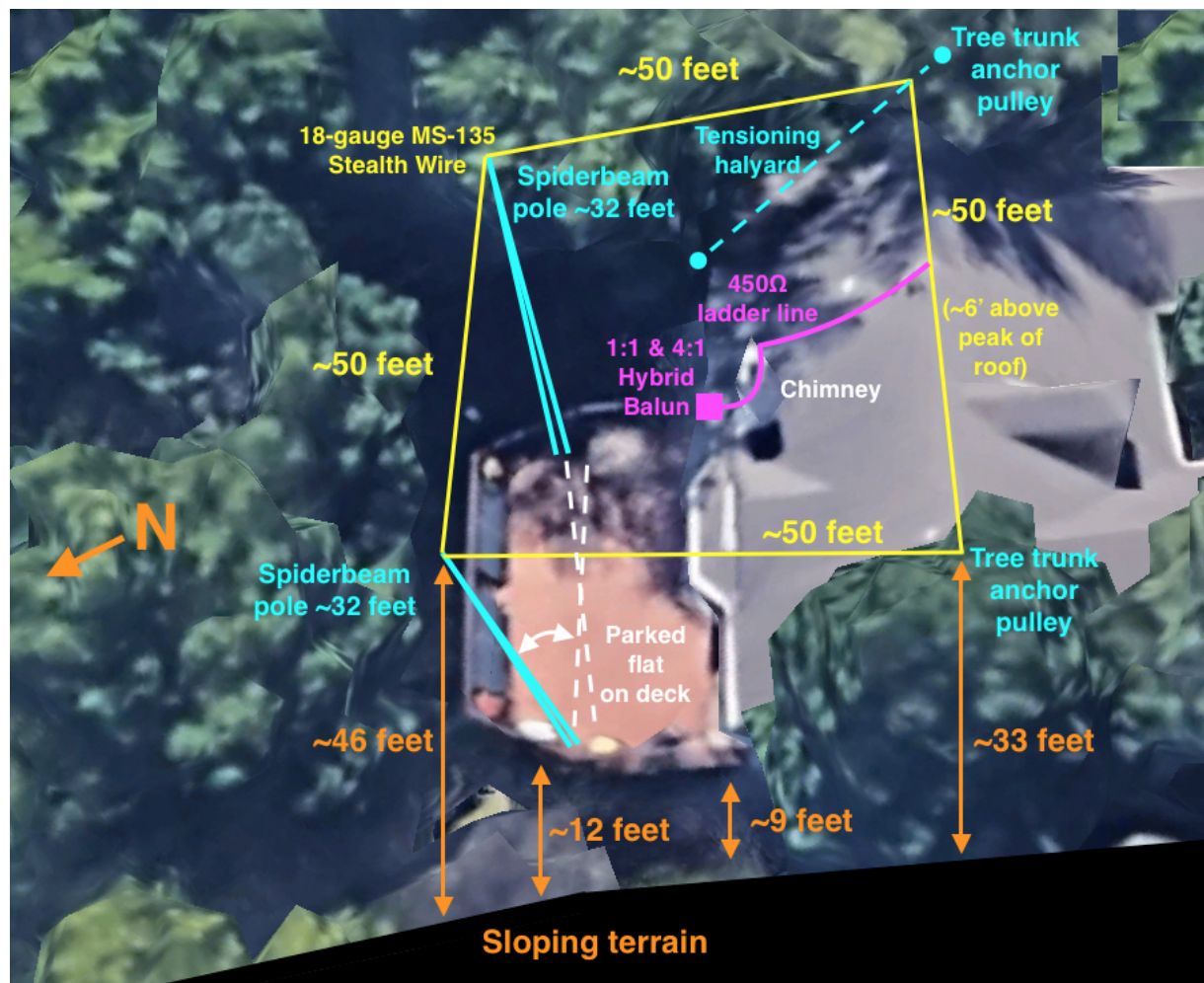
## (26) My early Antennas (HexBeam and Loops):

I have built and replaced a half-dozen multi-band loops over the past five years. They are good antennas except for the city noise on some bands (but Hen-Deltas are much quieter). My first was a 40m loop, then I built an 80m 'tree canopy' loop which worked well for a year before breaking in a storm, then a 60m loop (used for 6m-40m, not 60m) based on two Spiderbeam poles (shown at right in cyan, but now decommissioned) which I could fold down and access all wire and parts. now use an 80m loop carefully threaded through my trees so that it does not tangle in moving branches... or hasn't yet. Loops are broadband and easy to tune. If multiple wavelengths can be present on a large loop there will be more or less unpredictable lobes and nulls which will offer gain in some directions, but attenuation in other directions.

I typically use the 18-gauge MS135 stealth antenna wire for its invisibility and ruggedness. It has a breaking strength of 125 lbs or more.

Loop selection is via a homemade RF relay box on the antenna side of the 4:1 balun, and there is a Paradan surge suppressor/disconnect on the radio side of the balun, both located under the eave of the house for weather resistance.

For info about loops, search for: "The Long Wire Loop: an Omnidirectional, Multi-band, Low Angle Radiator" by Steve Cerwin, WA5FRF"



## 20m HexBeam:

July 2019: A deck-mounted 20m-only homemade HexBeam using schedule 80 PVC: Just ‘adequate’ performance due to its low wire height above ground – only 15’. The PVC eventually sagged in the summer heat – *fiberglass* is the best material to use. Decommissioned in mid-2020 as I wanted my deck back to build a modest off-grid, *educational* solar power system. As it turns out, there is a great deal to learn – a *most interesting* hobby project!

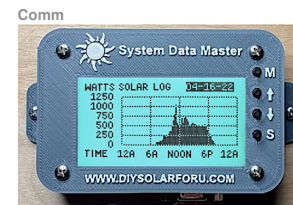
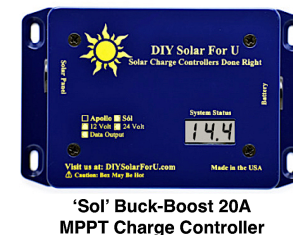


## DIY Solar Power:

Since this is off-topic I won't go into much detail, but if you ever wish to build your own DIY solar power system for amateur radio or other purposes, using *the highest quality* solar charge controllers and components, designed and built in Michigan USA to have a **40-year service life**, you can find them at this small business. I use several of their ‘Sol’ 20A Buck-Boost Charge Controllers (they also offer 16A, 7A, and 3A controllers), two of their Cell Balancers, and one System Master. *Zero* failures in 4+ years of 24/7 operation. The Chief Engineer has 30+ years of automotive micro-controller design experience and – being an amateur radio operator himself – minimal RF noise was a design criteria. See [https://www.diySolarForU.com/store/c1/Solar\\_Charge\\_Controller](https://www.diySolarForU.com/store/c1/Solar_Charge_Controller)

For an inverter I chose a true sine wave Samlex EVO-1224 (1200W, 24V) with its required remote panel for its *UPS-like* load auto-transfer grid synchronization (inverter-to-grid or grid-to-inverter) based on user-specified battery voltage **or** grid power failure. 1200W continuous with a *large* over-load tolerance for surges. It has industrial grade reliability with an admittedly *complex* setup menu due to its broad application versatility. It *does* produce significant HF noise on most bands – even with RF chokes everywhere – but that is common to all inverters so I just switch the inverter to grid when I wish to be on the air (radios can directly use 12V battery power). There are larger capacity inverters in the EVO product line – up to 4000W – and tech support out of Canada is excellent. Zero failures in 4 years. See <https://samlexamerica.com/product-category/inverter-chargers/>

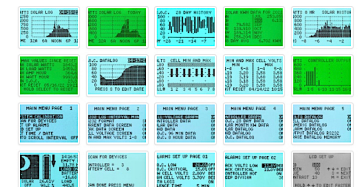
I mounted my indoor components – controllers, fuses, switches, the LFP battery and its auto-disconnect (heat, smoke detector, panic button), etc. – on a wheeled ‘refrigerator dolly’-like vertical backplane so that it could easily be transported if sold. The modest system supplies power for my amateur radio, two PCs, router, modem, small chargers (ie: tools, AA-, AAA-batteries) for ~8 hours (winter) to ~16 hours (summer) per day. The typical load is ~500W. When the LFP battery charge drops to ~35% (allowing for some spare reserve and also reducing cycle wear on the battery) the EVO transfers to grid power (it plugs into a wall outlet) until the batteries partially charge the next morning. During a brief grid failure it acts like a UPS.



System Data Master  
with Serial (to USB) Data Port



LFP Cell Balancer and Monitor



System Data Master sample screens

## (27) My ‘Shack’:

My compact ‘shack’ consists of an IC-7300 (my first and only HF radio) with a Palstar AT2KD differential tuner and, most recently, a Heathkit SB-1000 single 3-500Z tube amplifier capable of about 700W-800W SSB, depending on the band. This power level is a good fit for my antenna system because at 10m my RG-8X coax is limited to ~1200W SSB anyway, so a more powerful or ‘legal limit’ (1500W) amplifier would offer more power than I could take advantage of without an expensive coax upgrade.

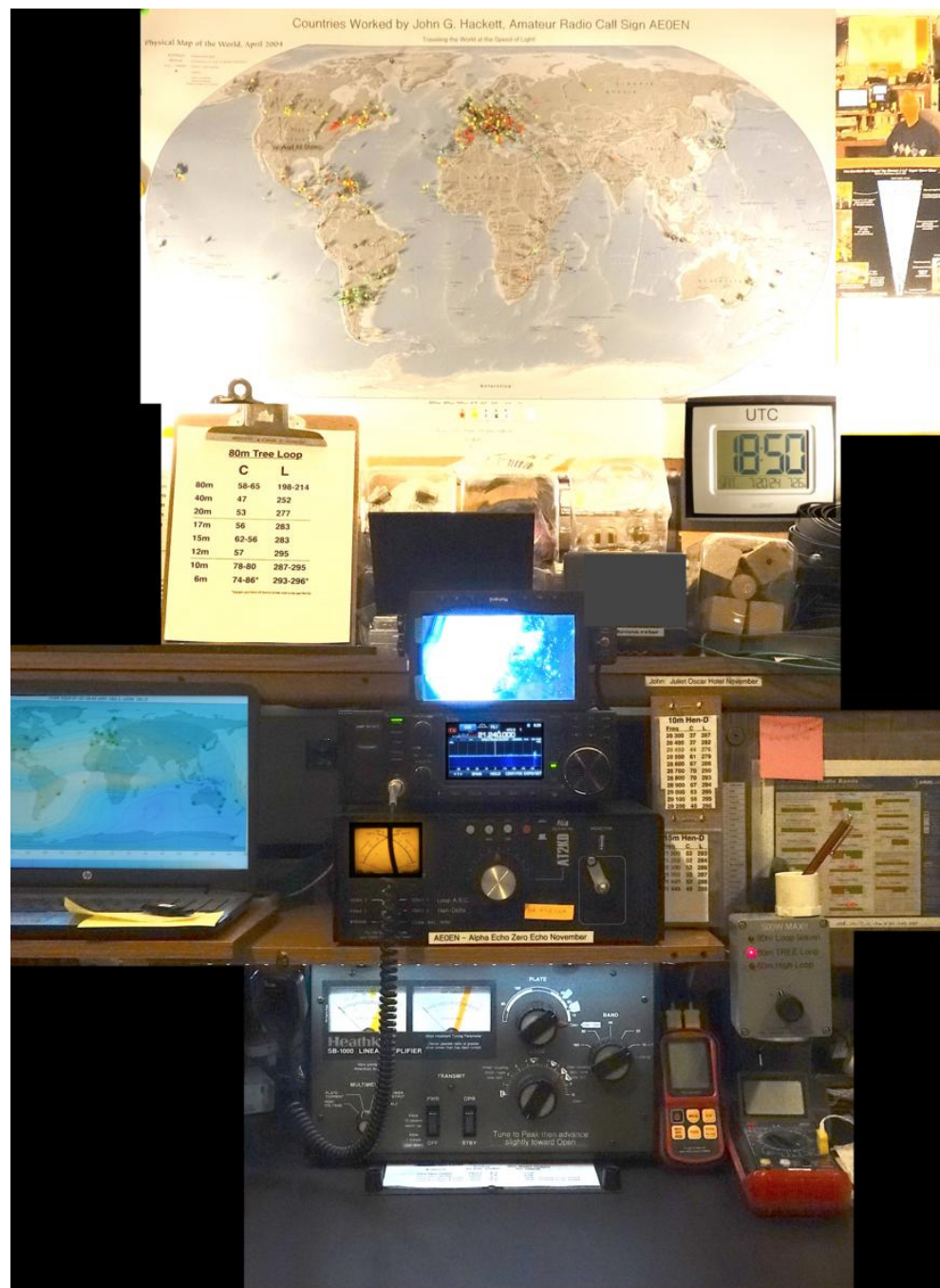
I enjoy adding new DX contacts to my ‘pin map’.

My coax is all RG-8X, about 65’ total to the near tree’s 40’ high 10m Hen-Delta antenna and about 90’ total to the far tree’s 55’ high 15m Hen-Delta. Thus both are about 1.2 wavelengths above ground at their top element – at which height they work very well for DXing.

My rotator is very simple and doesn’t offer position feedback, so I use a Rohent R4 1080p RV backup camera (Amazon) with a 7” HD monitor on top of my IC-7300. The system comes with two HD cameras. One of those cameras looks more or less straight up, and the other watches the marionette drive (described elsewhere). RV cameras are of necessity wide angle, so the antenna image size on screen is rather small, but the 1080p resolution easily shows the antenna’s orientation. At night the RV cameras use IR LEDs for illumination, and I added reflective tape to the ends of the top elements’ copper pipe, which makes them easier to see at night than during the day. This backup monitor offers image rotation, up/down and left/right image flipping and mirroring, which was crucial to match antenna rotation to the compass reticle. Not all RV backup systems offer so many image options.

The upward-looking camera has been mounted to align North to the top of the monitor’s screen.

**Chapter 22 provides more detail.**



## (28)

### Heathkit SB-1000 Linear Amplifier (same as Ameritron AL-80A) ‘Illustrated’ Schematic:

2024-0729: As I increasingly struggled to work new and farther countries at 100W I began looking at used amplifiers from various online sources and then learning more about them on eHam reviews and elsewhere. In mid-March 2024 I found this amplifier a half-day’s drive away and the seller kindly took the time to demo it and explain how to use it. I’ve never used or seen the inside of an amp before, let alone a ‘prehistoric’ *tube* amp – this one used a single 3-500Z tube – but my studies had taught me that this tube was one of the best to have. So I gulped, took the plunge and brought it home.

I dislike mysterious ‘black boxes’ and started researching how these 1978 analog ‘critters’ function – the most modern component back then was a single red LED. As I began to pick up bits and pieces of amp lore I needed a place to keep everything for quick reference, so I enlarged the canvas of the only clean schematic I could find online, and placed all these items of information around the perimeter. As I read of recommended ‘mods’ or created my own, I would revise the schematic. As I learned about how a section of the schematic functioned, I added notes to the schematic and gradually ‘morphed’ it for both clarity and extra space. I don’t claim to be an expert, but I have a fair understanding of which circuits do which things, and how they do it.

When I started this process I had no thought of making it available to share with other amateurs. But over a three month period it transformed into a substantial source of ‘tube amp’ educational material. The links below are for the ‘Peer Review’ version v0.98. At full size it is about a 17MB PNG file (~7000 pixels wide x ~6000 pixels tall). The ‘thumbnail’ image on the next page is about 1/7th of full scale. This amp has many aspects in common with other tube type amplifiers, so the schematic may have some value outside of this specific model. If you are a ‘tube amp guru’ I would welcome any suggestions to improve either the schematic or to ‘mod’ the amp itself – I still have much to learn.

Select the file and it will download it to a new window. You may then need to save it to your desktop:

<https://bama.edebris.com/manuals/heath/sb1000/>

Drag the schematic’s image to your desktop and it will download, or there may be a download icon on the page:

<https://archive.org/details/heathkit-sb-1000>

**'Peer Review' Version**  
Suggestions for improvements, additional annotations, or clarification are welcome and may be sent to me via my email link on GRZ.com

0.98a

Heathkit SB-100D with (Brother TZ4) Labeling and Meter Limit acetate tape added by AEDON

Heathkit  
SB-100D LINEAR AMPLIFIER

Tuning Indicator  
Meter Limit

PLATE  
AUDIO  
VOLUME

TUNING  
540 1600  
Tune to Peak, then advance slightly toward Open.

POWER  
OFF 50W 100W  
TONE  
OFF 500 1000

Rear View Front View

My compliments and sincere appreciation to Beavis Buile of CBTs.co.uk who made freely available the original 'civic' Headhal schematic which I have extensively modified, annotated, and expanded upon as an aid in learning the circuit functionality of this, my first amplifier. My attempts to contact Mr. Buile via his website's contact form, his webmaster, past acquaintances, and via USPS mail were all unsuccessful. I am certain he would applaud my continuing his work and making this enhanced version of my SB-1000 schematic also freely available to radio enthusiasts.

A reasonable effort has been made to assure the 'as built' accuracy of this enhanced schematic but it may not be completely correct and no warranty, explicitly or implied, is made as to its accuracy. I claim no expertise in circuit design – I am an AMATEUR – and may be overlooking important consequences of my modifications, especially with respect to esoteric failure modes. Furthermore, other warblers will likely have been built differently or modified by previous owners, and thus may not match this schematic in every detail. **DO NOT USE YOUR OWN REASONING** to modify any of the high voltage (HV) power supply, the tube, and in other areas of the circuit. This high voltage is deadly and unforgiving. If you are not sure of your ability to safely troubleshoot or modify your own, **DO NOT ATTEMPT TO DO SO.** The availability of this schematic is not an encouragement for others to alter their own, especially if you have done, or if you are doing. **DO SO AT YOUR OWN RISK.** This enhanced schematic should be considered EDUCATIONAL material.

Suggestions for improvements, additional annotations, or clarification are welcome. Note that this is a very high resolution jpeg and thus may not render well at lower resolutions. T3! John AEDB



## (29) Contact

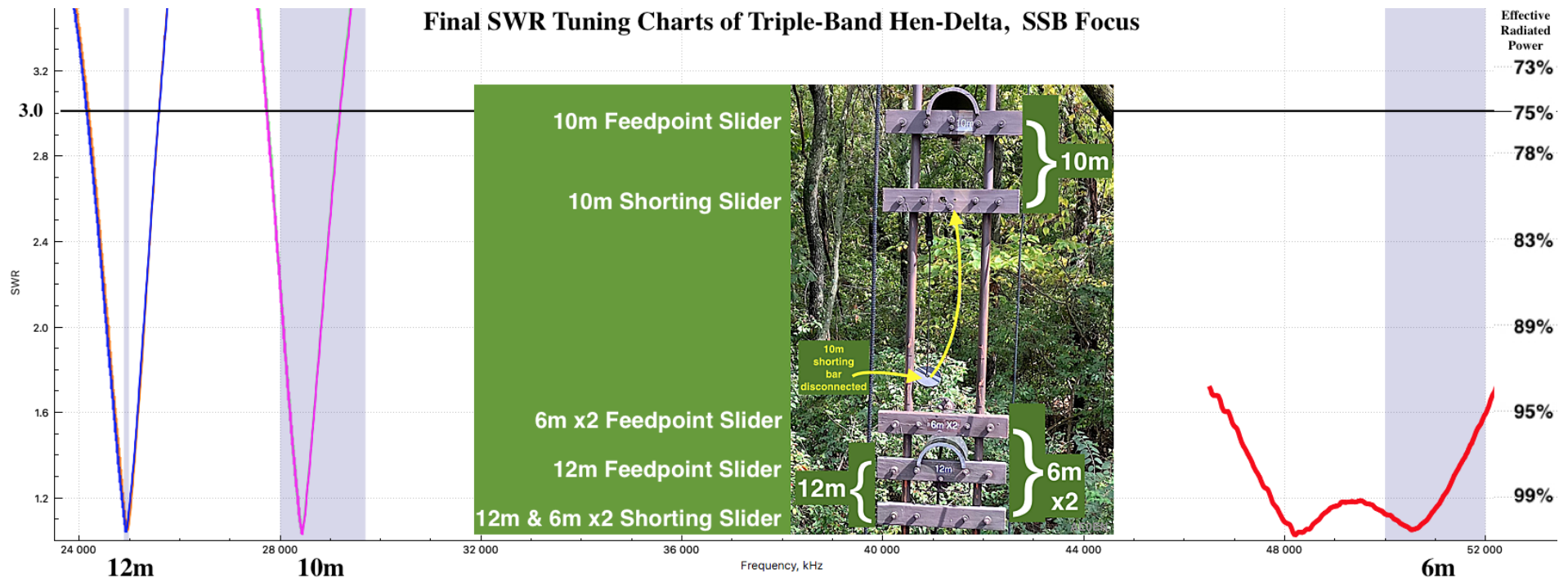
I would welcome carefully considered inquiries or comments from other amateurs about your experiences with, or knowledge of, Hen-Delta antennas, improvements that you have made or that might be attempted, and comparisons with other antennas. You can reach me via the email link on my QRZ page, but ***before emailing me with specific questions about this paper, please STUDY this paper thoroughly and carefully.*** The vast majority of what I have learned about the caged Hen-Delta antenna is ***right here!***

That said, if you study this paper with care and *still* have questions, then I probably should address or clarify those topics and points in this paper – so please *do* contact me via the QRZ page email or mailing address!

I would especially appreciate assistance with computer simulations if your software can cope with a ‘skeleton slot’ Hen-Delta geometry well, and if you have the time and interest. Some simulation engines are more limited than others and I don’t know enough about them to suggest which would work best. Also see page 114.

73! – John AE0EN

# Appendix 1: Adding a 6m *2-wavelength* tuning point to the 10m/12m Hen-Delta:



It is most unusual to use one shorting slider for two bands, but the alignment was so close that there was no room for *both* a 6mX2 *and* a 12m shorting slider. There are workarounds but they are unnecessary since the SWR curve is really quite good as is – an SWR minima under 1.2 is an ERP >99%.

Operating a horizontal loop antenna on multiple bands is so routine most amateurs don't give it a second thought. But the Hen-Delta is *also* a loop antenna and thus should support multiple wavelengths as well. This obvious reality dawned on me recently when I was thinking about adding a coaxial relay (see Appendix 2) to remotely select the 10m/12m bands, and happened to notice 6m activity on DXmaps: 12m... 6m... 6m times 2-wavelengths is ~12m... it's a *loop*, so why not? Adding an older pair of tuning sliders and adjusted them with my RigExpert AA-230 Zoom resulted in the configuration shown above – the '6mX2' *shorting slider* wasn't needed since the 12m shorting slider *happened* to be positioned close enough to serve double duty. The 6mX2 SWR curve is very broadband (note the *double* minima) and quite efficient even if the minima only attains 1.15 (ERP >99%) in the lower SSB region – especially for a rarely

used band. At 40' above ground, 6m would be 2-wavelengths above ground, for a very low elevation angle (take-off angle).

**This opens up the possibility of other permutations:** A 15m/17m Hen-Delta might support 6mX3 (three 6m wavelengths as an 18m tuning stub), and also 20m (each longer wavelength at a reduced efficiency, of course). If 20m is supported then 10mX2 could be supported as well, suggesting a 5-band Hen-Delta might be possible, consisting of: 6mX3, 10mX2, **15m** (Primary band), 17m, & 20m. This is intriguing and worthy of further investigation...

...One interesting variation is the use of a second, identical Hen-Delta as a reflector with a tuning stub long enough to support a 105% wavelength tuning point (or 95% of frequency – same as a yagi). This reflector could be made to

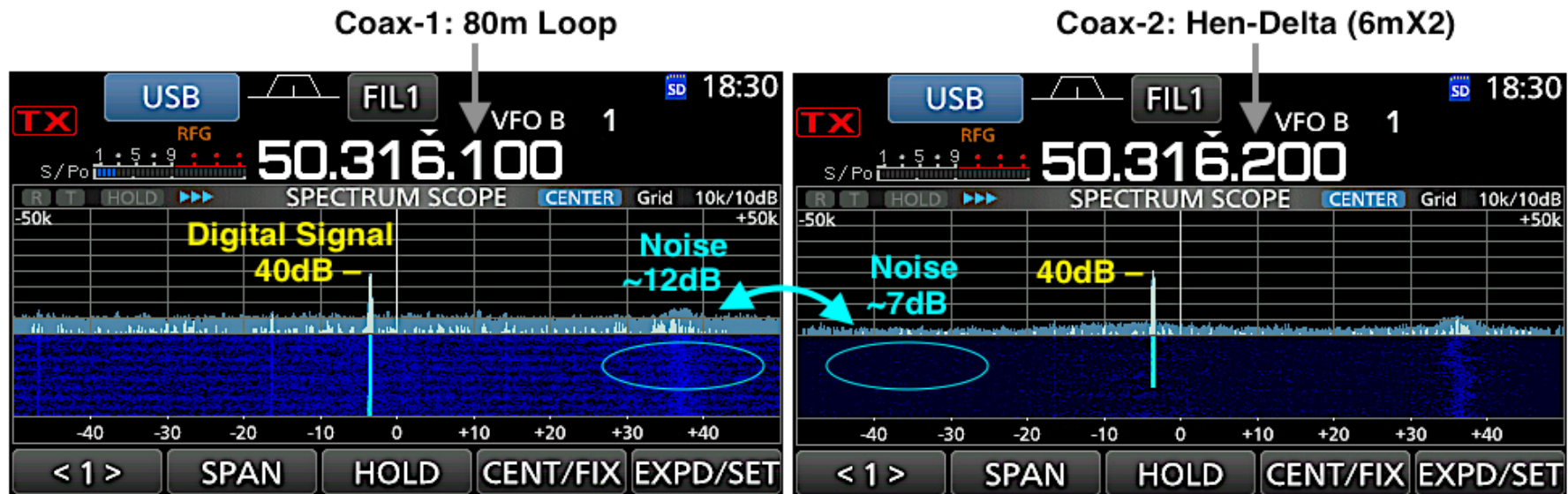
‘disappear’ using the same ‘relay opening’ technique as described in Chapter 22, resulting a normal Hen-Delta with no reflector. The two identical Hen-Deltas could also reverse functions based on which antenna’s tuning stub was driven and which was switched as the reflector. This would limit the rotation requirement to 180° rather than 360°. These possibilities are just interesting consequences of a versatile tuning stub.

I have been attempting to verify that the 6mX2 tuning point performs as one would expect. This has been difficult because 6m – ‘the magic band’ – hasn’t been all that magical lately. I did on one occasion hear both CW and SSB, but the operators were working ‘DX Aurora’ SSB which was incredibly distorted – I haven’t heard it before. DXmaps has been showing 6m propagation ‘here and there’ – New York to Kentucky to Florida and *many* Europe to South America ‘spots’ – but not to *this* area of the midwest. I will continue to watch and listen and hopefully make my first 6m QSO via the 6mX2 antenna.

Meanwhile I did catch this digital signal at 50.312 and captures the IC-7300

screen for both the 80m Horizontal Loop antenna and the Hen-Delta 6mX2 tuning point. Being digital the amplitude was constant, which was helpful. Both antennas showed the same 40 dB amplitude (4 Y-axis grid lines at 10dB each), but the Hen-Delta showed a much quieter background noise level – about 5dB less. This is consistent with Hen-Delta vs Loop experience on other bands and is one of the joys of the Hen-Delta antenna.

I can’t draw any conclusions about the signal’s relative strength on each antenna because the 80m Loop carries about 13 wavelengths of 6m and the resulting azimuth pattern of lobes and nulls resembles an irregular ‘daisy’ – there is no way to know if I am receiving near a lobe or near a null? I did rotate the Hen-Delta and saw the digital signal drop by 10dB at the Northwest-Southeast beam direction, then slowly return to 40dB at the East-West through Northeast-Southwest beam direction. So the Hen-Delta 6mX2 tuning point is almost certainly performing as it should. Nevertheless, I will continue to look forward to having a confirming 6m SSB QSO someday.



*The .1 and .2 frequency suffixes match the tuner’s input switch (loop or Hen-Delta) and just ensure that the two screen captures were not confused with each other.*

## Appendix 2: Remote Selection of Hen-Delta Bands via Coaxial RF Relays:

The addition of two relays to the primary 10m tuning stub is conceptually easy but mechanically a bit awkward looking. The SPDT RF relay connects the 10m tuning stub (NC) or, when powered, the 12m tuning stub (NO). The NC double-break relay (Midland Ross 188-35B200 or 188-25B2U1 from [rfparts.com](http://rfparts.com)) completes the 10m shorting slider (NC) until power is applied at which time it opens, allowing the 12m shorting slider stub about 24" further down the copper pipes to become effective. Note that both relays are powered at the same time by the same 12V power cable, which is suspended next to the coax cable. The double-break style of relay is ideal, but other styles of relay would probably work, too.

12m functionality was confirmed during a QSO with Japan. He was using 200W and a 5-element yagi directed at North America, I was using 700W bidirectionally aimed at Japan and South Africa, so 350W was directed at Japan. Both signals were strong 59s.

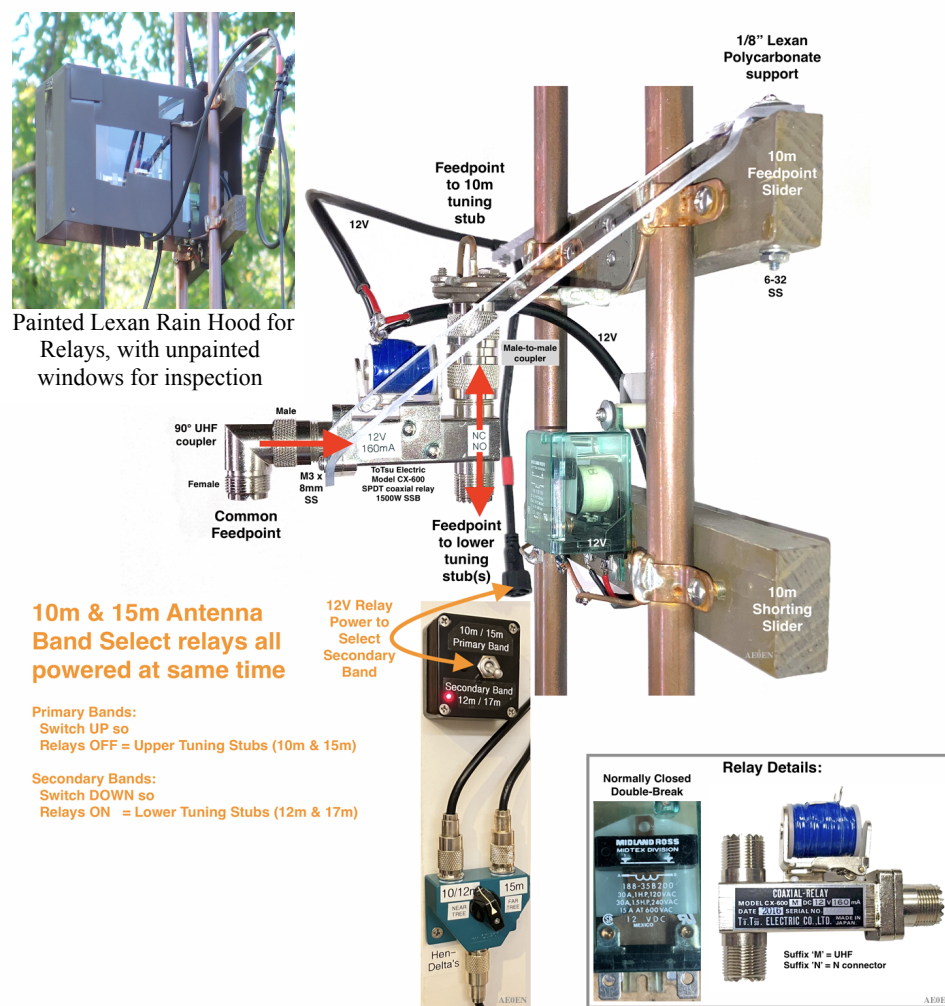
For this tuning stub configuration the 6mX2 band must be **manually selected** by moving the 12m band's feedpoint coax. Since the 12m and 6mX2 feedpoints happen, by chance, to share the *lowest* shorting slider, no other action is needed. If that were not the case then the shorting *bar* (see section 6a and 6b) on the middle shorting slider would need to be manually reversed. In other words, the antenna can be configured as either 10m/12m or 10m/6mX2.

A multi-position coax antenna switch combined with multiple shorting relays could allow for complete remote selection of all possible bands, but at the price of greater complexity. It would be handy if the coax switch offered auxiliary output connections for the shorting relays.

**An alternative (at left) would** be to ‘cascade’ these SPDT RF relays down the tuning stub, each relay feeding its tuning stub and shorting relay, or passing the signal down to the next relay pair. This could utilize a multi-position rotary power switch with diodes to sequentially power each tuning slider pair of relays and all preceding band relays: Band ‘A’ (default band, no power), then band ‘B’ (power to band ‘A’ relays), then band ‘C’ (power to both band ‘A’ & ‘B’ relays), etc.

There is a device called a 'Bias-Tee' (see Wiki), which can inject DC power onto coax and then recover it at the antenna, making a separate power cable

## Remote Selection of Hen-Delta Bands via Relays



**You may zoom in on this image.**

unnecessary. While I have never used one, I like the specs of the 'BIAS.T' from *Tactical Radio Gear* dot com ( $\pm 50\text{VDC}$ , 6A, 3KW RF, \$89 as this is written, Made in USA).

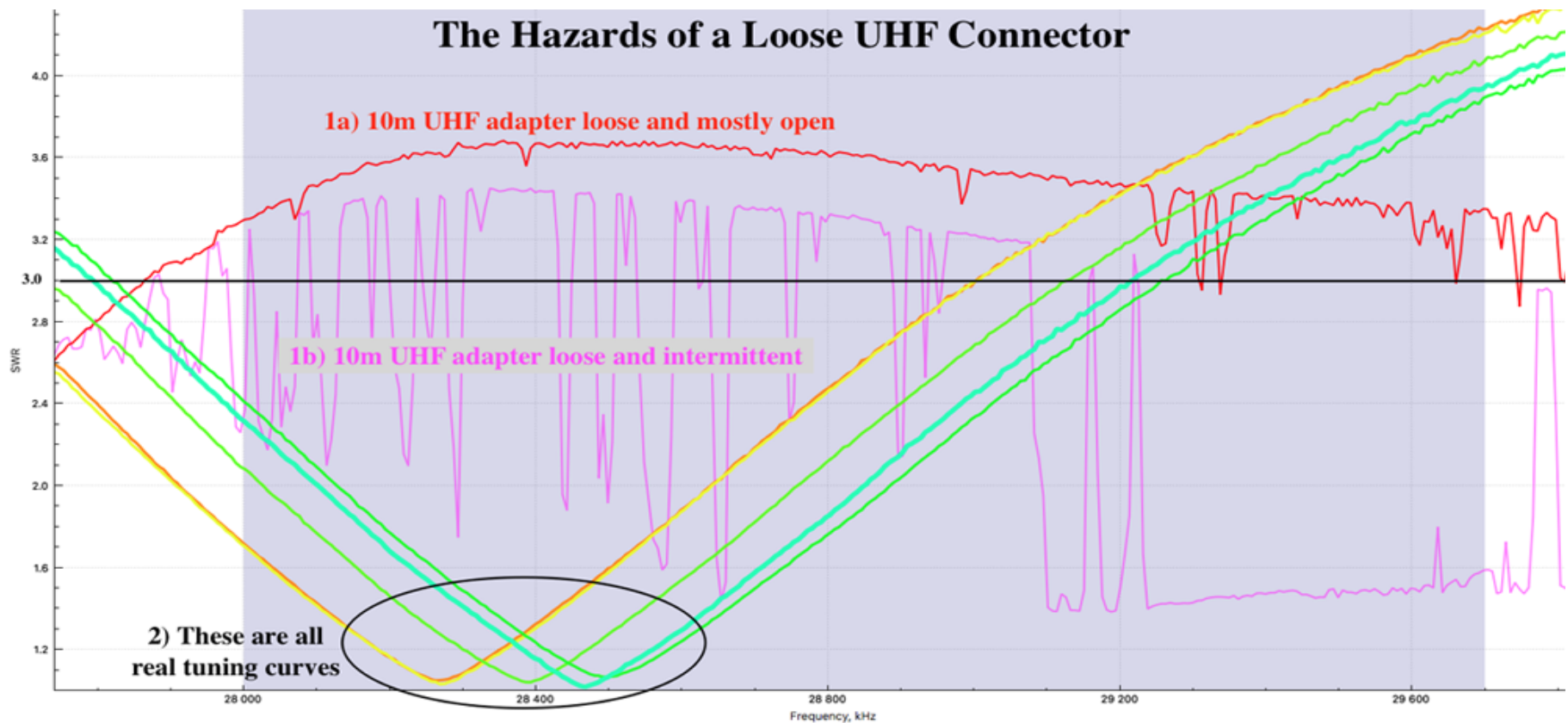
1/8" Lexan polycarbonate was used as a support strut to secure the RF relay so that it wouldn't pivot at the UHF connections. Polycarbonate is a very strong

material that can be bent and shaped with a heat gun. 1/16" polycarbonate sheet (Amazon) was bent in an improvised homemade 'brake' to create a custom, two-part, lightweight rain hood (see inset at right). A simple SPST switch (previous page, lower center inset) powers the two relays to utilize either the upper sliders (switch up for 10m) or the lower sliders (switch down for 12m/6mX2). Don't forget to add a flyback diode, either at the switch or at the relays, or you will destroy the LED indicator.

### The Hazards of a Loose UHF Connector:

Antenna tuning doesn't always go smoothly! This attempt was inexplicably random and quite frustrating, with SWR traces sometimes well-behaved, sometimes slightly shifted... and sometimes wild (see #1a and #1b below)? What *on Earth* was amiss? I checked and eliminated several possibilities, hoping it wasn't a bad coax cable or failing coax connection as those can be tricky to lo-

cate... then discovered that the **male-to-male UHF adapter** on top of the RF relay (see photo on previous page) wasn't *completely* tightened to the relay. Good grief! It required two more complete turns of the adapter's *coupling ring* using pliers. Sometimes those coupling rings stick due to a small burr on the threads – especially when new, as these were – seemingly tight but not completely so. The coupling ring is *not* the RF connection, it's purpose is to force the two connector bodies of the PL-259 and SO-239 together under compression. Once the connection was truly tightened the SWR traces again became well-behaved and *stayed that way!* (See group #2 below).



# Appendix 3:

## How does the Hen-Delta compare to other antennas for DX?

This casual illustration shows my best guess as to how the caged Hen-Delta performs for DX compared to other antennas.

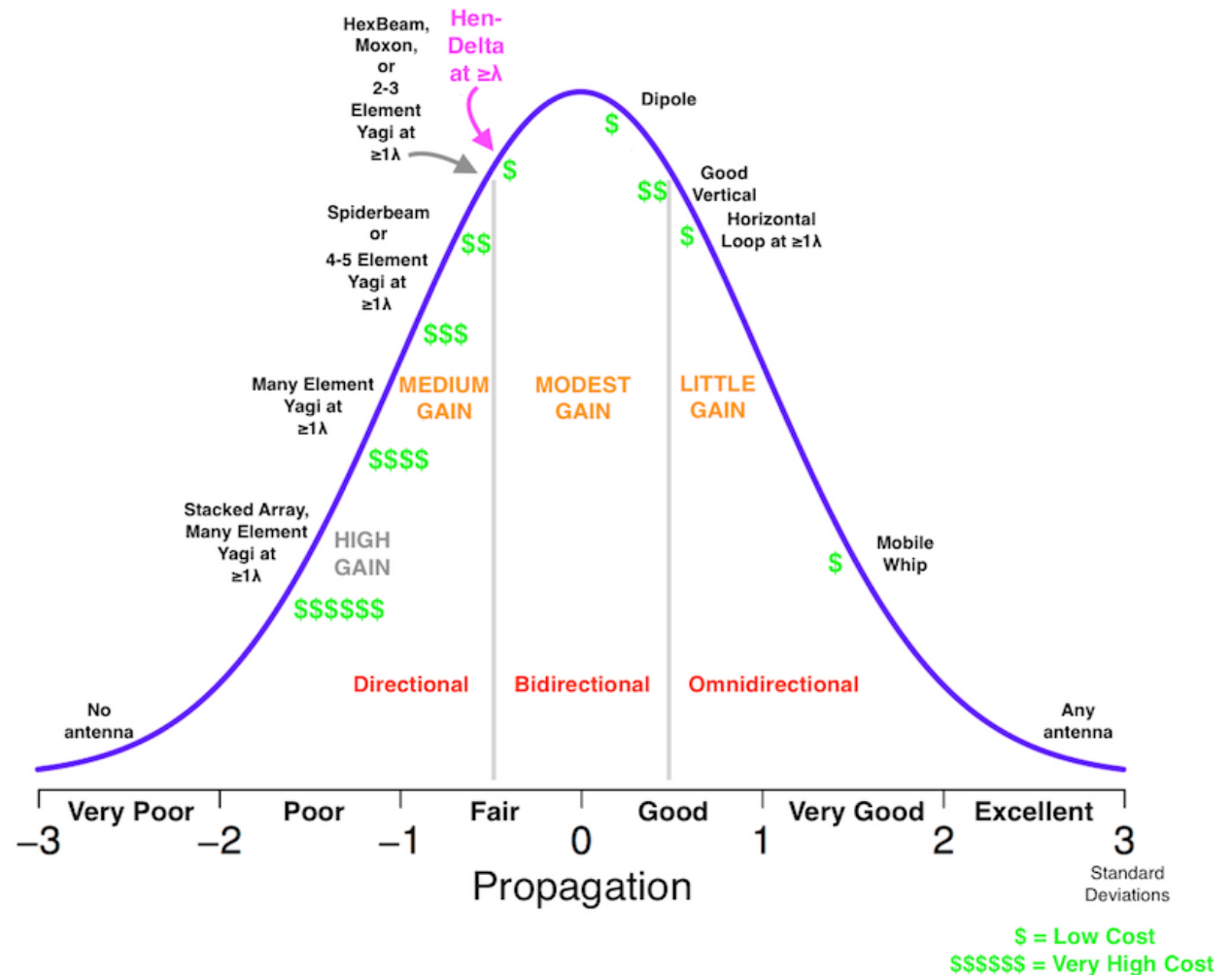
As a *bidirectional* antenna it will outperform any *omnidirectional* antenna. It will also outperform a simple dipole, and with lower noise (a higher signal to noise ratio).

It has a broader bandwidth than a yagi of similar gain.

Even though it is *bi*-directional, its performance has been compared to a 2-element yagi, which is a *uni*-directional antennas. This is partly due to its skeleton-slot nature, offering lower elevation (take-off) angles. It should be noted that experiments described in this paper suggest that a reflector *could* be added to a Hen-Delta for an additional 3db of gain (similar to a 4-5 element yagi but much more broadband), but optimized dimensions have not been simulated. Assistance with this task is needed.

The Hen-Delta is a **low cost, easy to build** antenna of relatively **low weight** and **self-supported** (suspended) from a **single point**. It does *not* require elaborate booms and complex, precision construction. It is compact with a tiny turning radius, tolerant of dimensional 'informalities' during construction, and easy to tune – even with two or three bands on the tuning stub.

## Subjective Illustration of Minimum Antenna Needed for Typical DX vs Propagation



## Appendix 4: ‘Carrier Trolley’ Concept for use with metal flagpoles or metal structures:

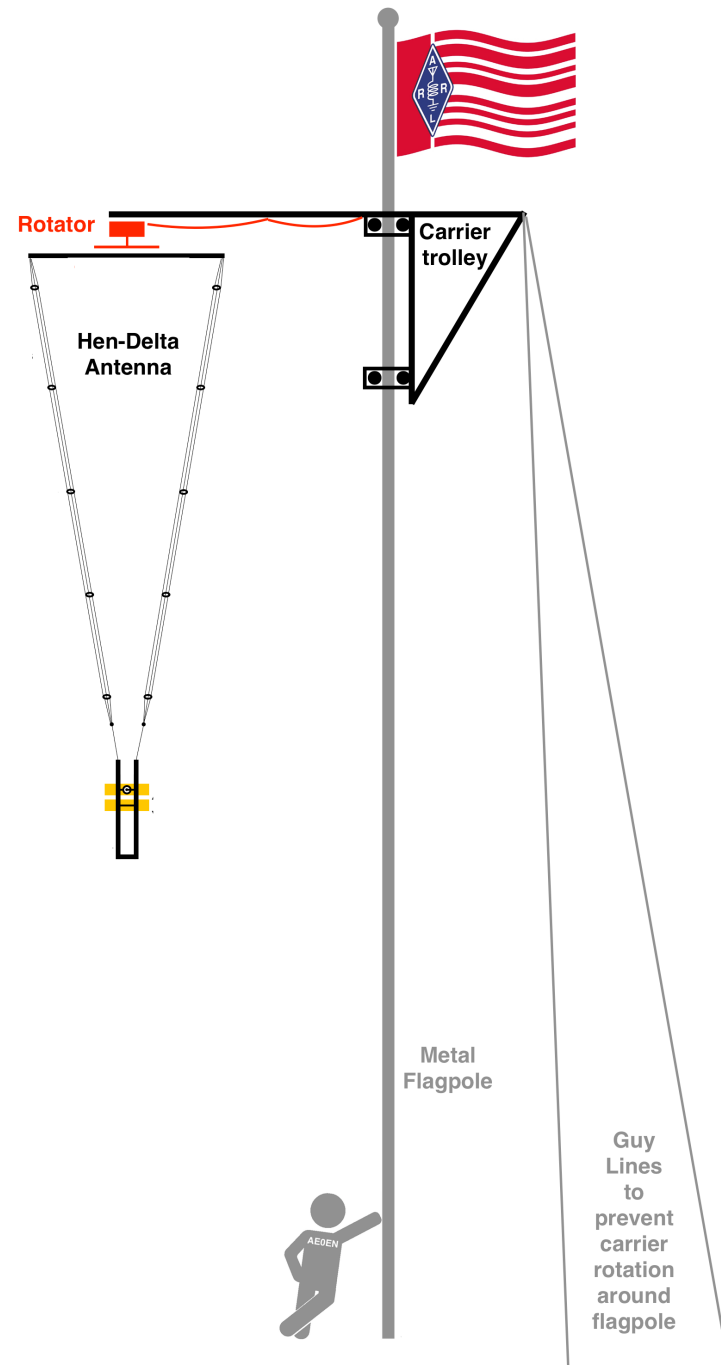
If you happen to have access to a tall *metal* flagpole or other *metal* structure like a tower, you might consider a lightweight ‘carrier trolley’ or ‘tram’\* that could be raised by a rope and pulley. It would support the Hen-Deltas antenna and its rotator on a lateral standoff beam or spar to keep it appropriately distant from the metal pole or structure. There would still be considerable interaction when the antenna beam was aligned with the pole, but this could be managed.

In the event that a trolley-mounted rotator isn’t available or needed, steering lines could be attached to the Hen-Delta itself and either manually controlled or attached to a rotator on the ground.

The rotator drive could also be attached *at* the carrier trolley near the pole or tower and a non-conductive drive system created to rotate the Hen-Delta. This would reduce the weight on the spar to just that of the antenna and some non-conductive drive components.

The illustration shown at right is just a simple sketch and better designs could certainly be devised.

\*For towers there exists a conceptually similar, but very heavy duty product called a ‘*Hazer*’, described as a cable-driven tram or elevator system for moving an antenna from ground level to the top of the tower. Note that with a tower – or any non-cylindrical structure – the guy lines shown are not required.



# Appendix 5: A 6-Band, 6m-20m Hen-Delta Antenna (7-bands if 11m CB is added):

2025-0227: A multi-band 10m/12m was built and described in Chapter 6b (also see appendix 1). Here I will describe the construction of a Hen-Delta with three *remotely-selected* bands:

- 1) 15m (primary band), always available (dimensions in Chapter 20)
- 2) 17m, always available (with 'free' 6mX3)
- 3) One of the following three manually-connected options,
  - a) 20m
  - b) or 10mX2
  - c) or 12mX2

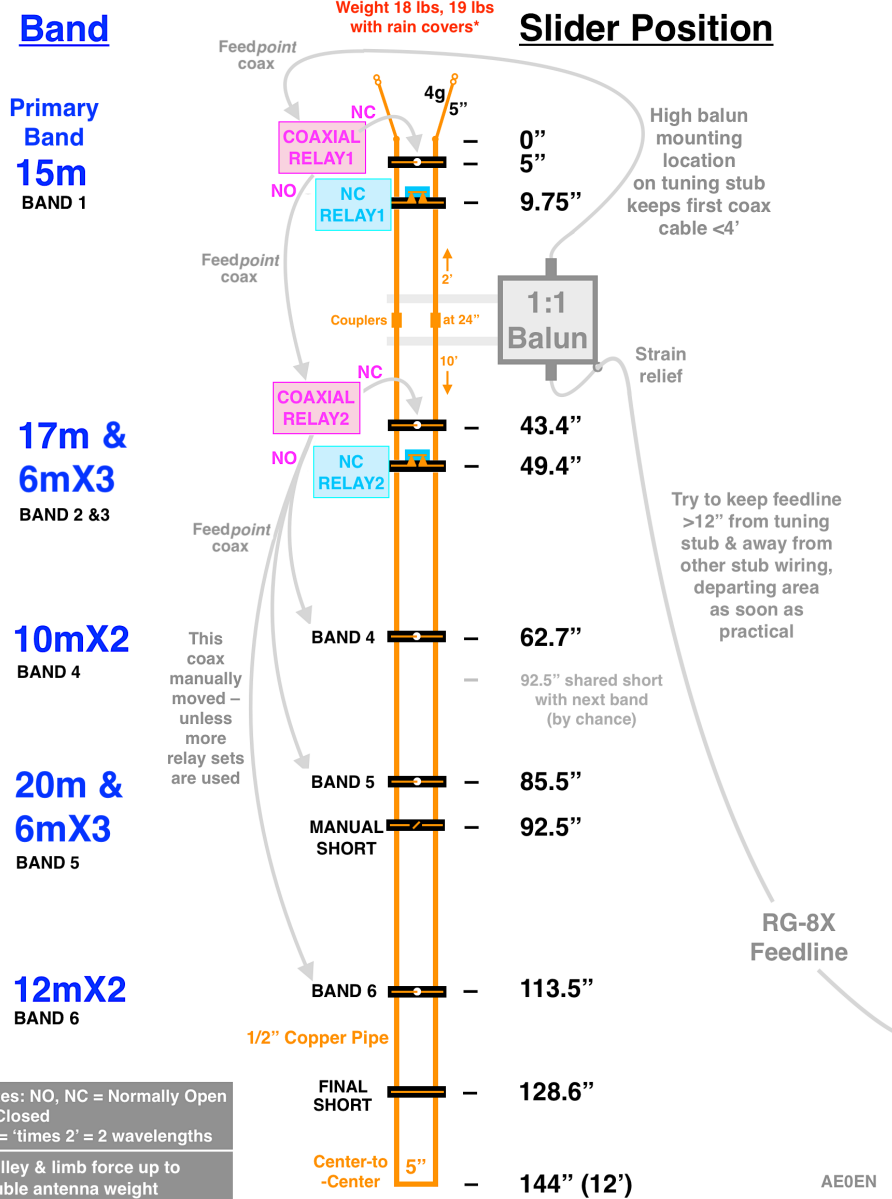
Because the Hen-Delta is a *loop* antenna, multi-wavelength tuning points are possible. The 6mX3 (**X3 means 'times 3', or three wavelengths** of 6m) *could* have had its own independent tuning sliders, but by chance was sufficiently resonant on other bands (see next page) that I decided to forgo the additional effort. My use of 6m is rare so I appreciate that this band, by chance, is 'free'!

Two (expensive) coaxial relays (CX600M or similar) remotely select from among the three options shown above. This is accomplished with a two-wire 12VDC cable, and DC polarity control, shown symbolically at right and discussed in greater detail later. Band-4 (10mX2) appears to missing its shorting slider, but by a happy coincidence during tuning we discovered that Band 5's shorting slider at 92.5" was nicely positioned for it. Thus to change between 10mX2 and 20m it is only necessary to move the coax connector between those feedpoints. To use 12mX2 the coax is moved and the shorting slug (switch) at 92.5" is removed (opened) and left to dangle by it's tether cord. The 12mX2 shorting slider ('final short') is a simple, non-switchable 12-gauge wire.

If you choose to build your own multi-band Hen-Delta your tuning sliders will certainly be at different distances than as shown at right – every construction detail effects them slightly. As I mentioned previously, a graphing antenna analyzer is required.

This tuning stub is the heaviest I have ever built at **19 lbs** (with antenna, **25 lbs**). You may need help wrestling it up and down! I constructed a homemade capstan drive (p105) to do the heavy lifting. Please remember that with the use of an overhead pulley to support an antenna, the load on the pulley, J-hook, and

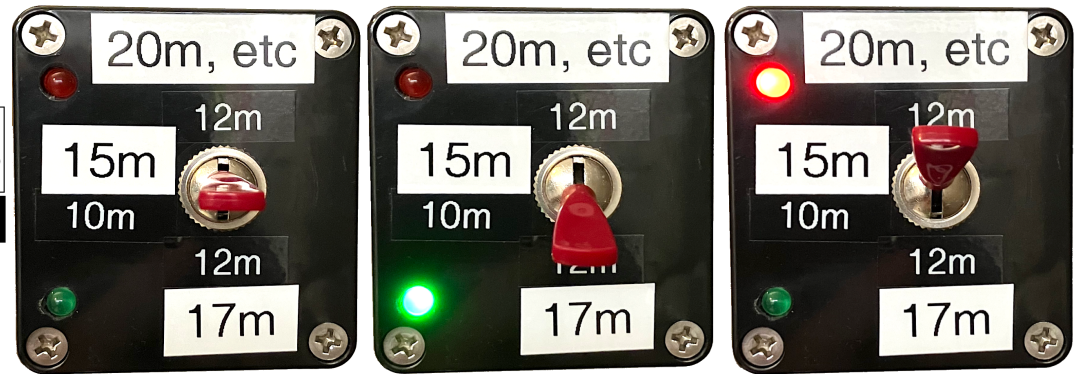
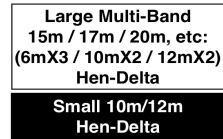
## 6-Band Hen-Delta Tuning Stub Layout (as built)



anchor point (tree limb) can be up to *twice* the weight of the antenna. This requires that attention be given to 'weak links' during J-hook construction and possible dynamic forces from wind gust loading.

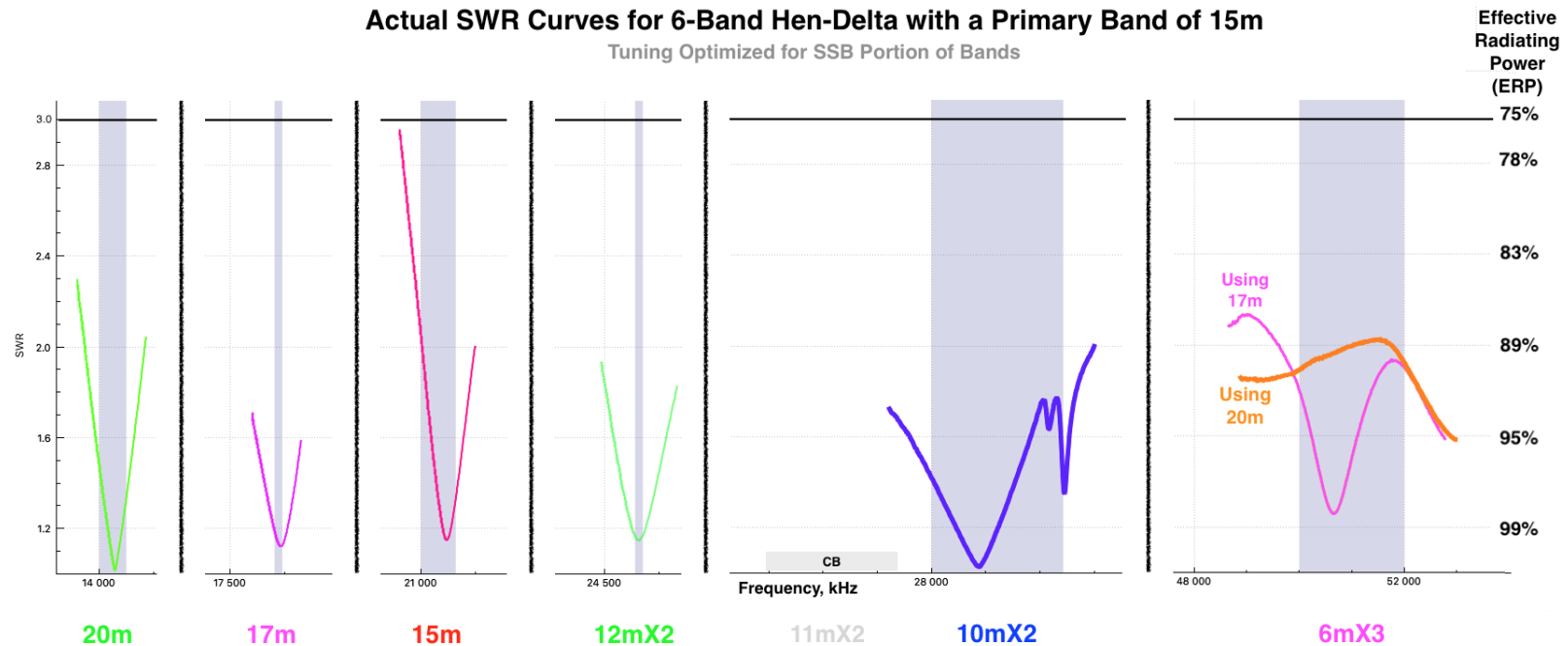
At right is the simple DPDT switch controls the three relay states to select the desired band for my *two* antennas. The smaller Hen-Delta is a 10m primary with a 12m option (smaller white-on-black lettering). The 6-band, 6m-20m uses all three positions (larger black-on-white lettering).

It is possible to improve the SWR curves above with further fine tuning of slider positions  $\pm 0.1''$  or so, but with ERPs  $> 99\%$  it isn't worth the effort at this time.



11mX2 CB was untuned but I have listened in to confirm that the band functions. CB is normally vertically polarized and the Hen-Delta produces horizontal polarization.

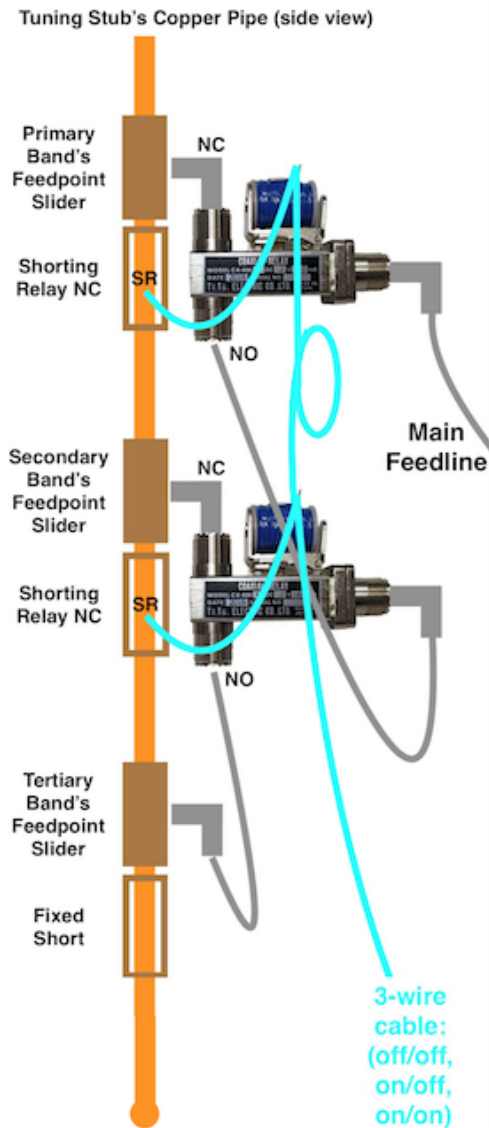
### Tuning Optimized for SSB Portion of Bands



It has been pointed out to me (thank you!) that the above SWR curves *include* the 75-foot RG-8X coax run and thus the **ERP scale** at the right (and on all other such charts) may therefore not be equally accurate for *every band*, depending upon actual coax losses, which vary significantly band by band, mostly effecting higher frequencies like

6m-10m. I accept this as a point for future study and better illustration, but I don't believe it materially alters the results. But do note that ERP may be worse than shown at higher frequencies like 50MHz.

## Cascading Relays for Remote Band Selection



*This relay topology worked!*

### Cascading coaxial relays vs centralized relays:

My original relay topology for the 2-band 10m/12m Hen-Delta was cascaded (as at left, but with just a single CX600M relay), and it worked well. During the construction of the 15m-20m Hen-Delta I attempted a wiring simplification which put all the relays proximate to the 1:1 current balun, as shown at upper right. This topology was tunable on 15m, but 17m and 20m **would not tune!** Substituting the manual coax switches at lower right showed the same problem. I believe this was due to the two coax cable runs from the relays or switches being continuously connected at the 17m and 20m feedpoints, **and thus inadvertently adding unintended additional stub length to those bands.** The solution was to return to the cascaded relay topology (left) with two CX600M relays, and the antenna then tuned gracefully on all three bands.

The lowest feedpoint coax (for 20m in the example at left) may be *manually relocated* to other nearby feedpoints such as 10mX2 or 12mX2 when those feedpoints are too infrequently used to justify the cost of a dedicated CX600M relay.

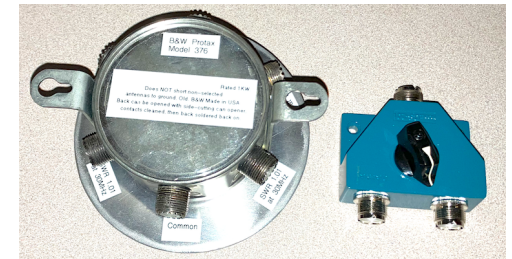
Note that ToTsu Electric Co.'s CX600M UHF relays are still in production in Japan today, but are pricey at \$120-\$130. Nonetheless, I recommend purchasing these relays *new* unless you know the seller. On p95 I show the 'Hail Mary' repair necessary to one such relay.

It is simplest to use a 16- or 18-gauge power cable with one wire for each relay set plus one for the common, however, it was convenient for me to use a two-wire cable and powered the 2<sup>nd</sup> relay via a diode, providing three states:

|        | Relay Set-1 | Relay Set-2 |
|--------|-------------|-------------|
| 1) 15m | Off         | Off         |
| 2) 17m | On          | Off         |
| 3) 20m | On          | On          |

Were I to add a 3<sup>rd</sup> relay set, or more, I would *have* to run a new multi-wire power cable and build a new selector switch.

Note that the Normally Closed (NC) Shorting Relays are powered (opened) at the same time that their associated coaxial relays are powered to send RF to the next band down the tuning stub. Two relay sets (a set is one coax and one shorting relay) provide for three remotely selected bands. Three relay sets would provide four bands, and four relay sets would provide five bands. Note that both the CX600M and the Midland Ross 188-35B200 (and very similar 188-25B2U1) 'double-break' relay coils (see Chapter 22) are rated for 12VDC, but have been tested operational down to 10VDC at the antenna. While the shack's power supply provides 13.8V, there is some voltage drop in the 100' of 18-gauge power cable and 0.7V in the silicon diode used to block activation of the **2<sup>nd</sup> relay set** unless the correct polarity is supplied via the DPDT switch. We measured 11.3V at the 2<sup>nd</sup> set (both relay sets powered = 4 relays total load, plus diode), which is within operational specifications. The 1<sup>st</sup> set (2 relays total load, no diode) measured 12V. A cleaner design would have used 18-gauge, 4-conductor wire to provide one common wire, one wire for each of the two re-



*NONE of the above three centralized coax switching topologies worked!*

lays sets, and one spare wire for a future 3<sup>rd</sup> relay set. I place RF chokes at both ends of the 12V power cable. By the way, I *have* seen replacement relay coils for the CX600M relays sold separately in case they are damaged.

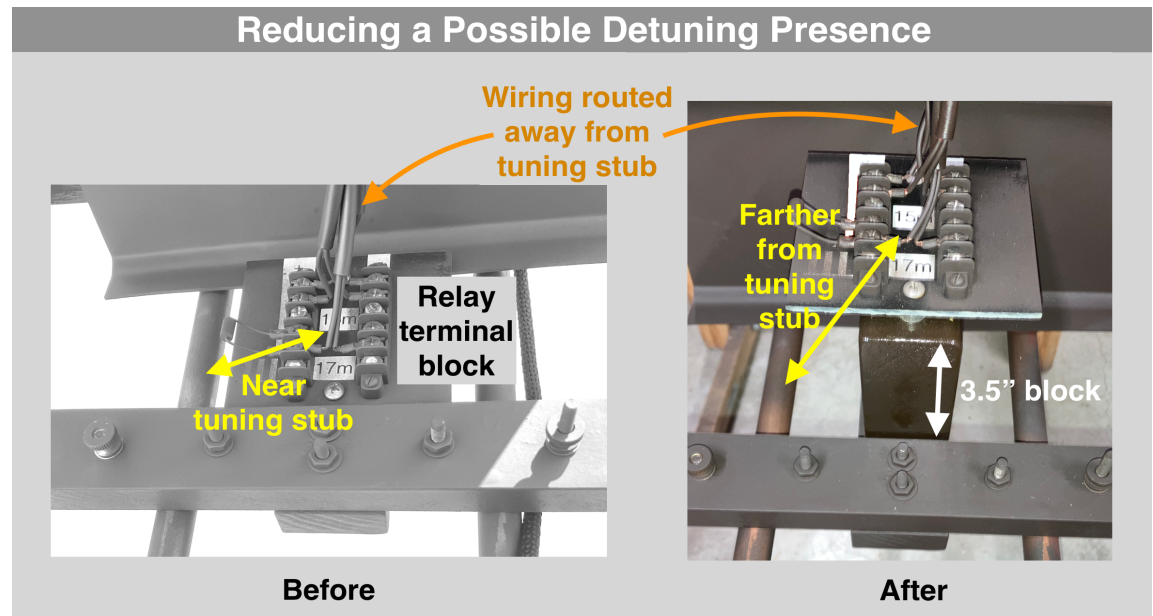
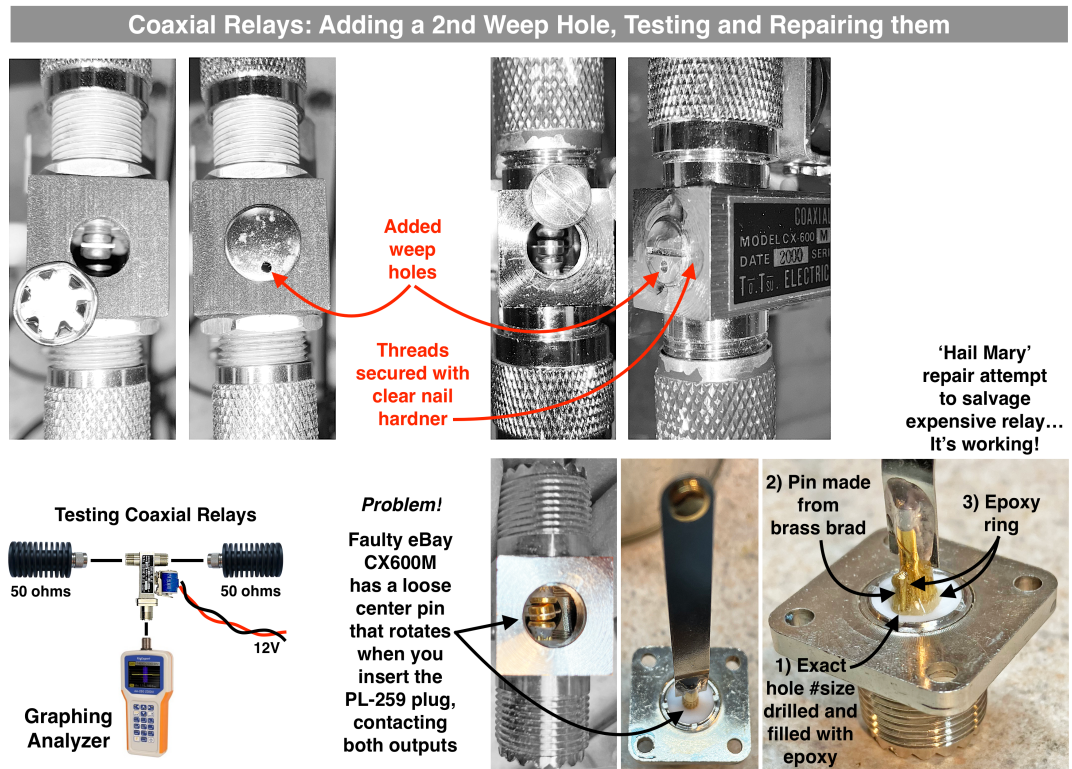
These expensive RF relays are excellent, low loss, and are rated into the GHz range, but if anyone knows of a less expensive alternative relay that will switch *HF* at 1000W with low losses, I would like to learn about them.

### Coaxial Relays Testing, Repair, & Weep Holes:

Testing and adding a second weep hole is shown at right. Also a ‘Hail Mary’ repair attempt which is working so far. You may zoom into this image collage.

### Detuning Presences:

Tuning a six band Hen-Delta requires patience. *A lot* of patience! It is best to test a new multi-band Hen-Delta *manually* (no relays) at first, moving the feedpoint coax and shorting the appropriate slider one at a time. The bands need not be tuned perfectly, just close enough to see that they are well behaved. The Hen-Delta is a remarkable antenna and very tolerant, so if you find a band that doesn’t tune well, you should suspect that there is a construction problem of some kind, perhaps an ‘unrecognized detuning presence’ (see ‘*Reducing a possible detuning presence*,’ lower right). Remember that the two copper pipes (remarkably similar to *ladder line*) are *not* shielded from their surroundings as coax is, and metal, wires, and coax cable nearby will affect them – especially if they are free to move nearer and farther. I improved my entire SWR family of curves (two pages earlier) by ~0.1 SWR simply by re-routing the feedline to the 1:1 current balun. I originally had neatly organized it by running it through the fiberglass stand-off loops (see next page) *along side the feedpoint coax cables*, but the proximity of the feedline coax to the post-balun relay-fed feedpoint coax was a ‘detuning presence’. Also, the previous 17m SWR curve minima of 1.24 (not shown) was slightly detuned by the location of the relay terminal block (right). Its curve was improved to SWR 1.14 after the change shown here. Due to their proximity to the tuning stub I would also like to change the SO-239 mounting L-brackets from mild steel (see below) to stainless steel, but that is far too much effort for too little potential improvement at this time. A Hen-Delta is never ‘bad’... just ‘misunderstood’!

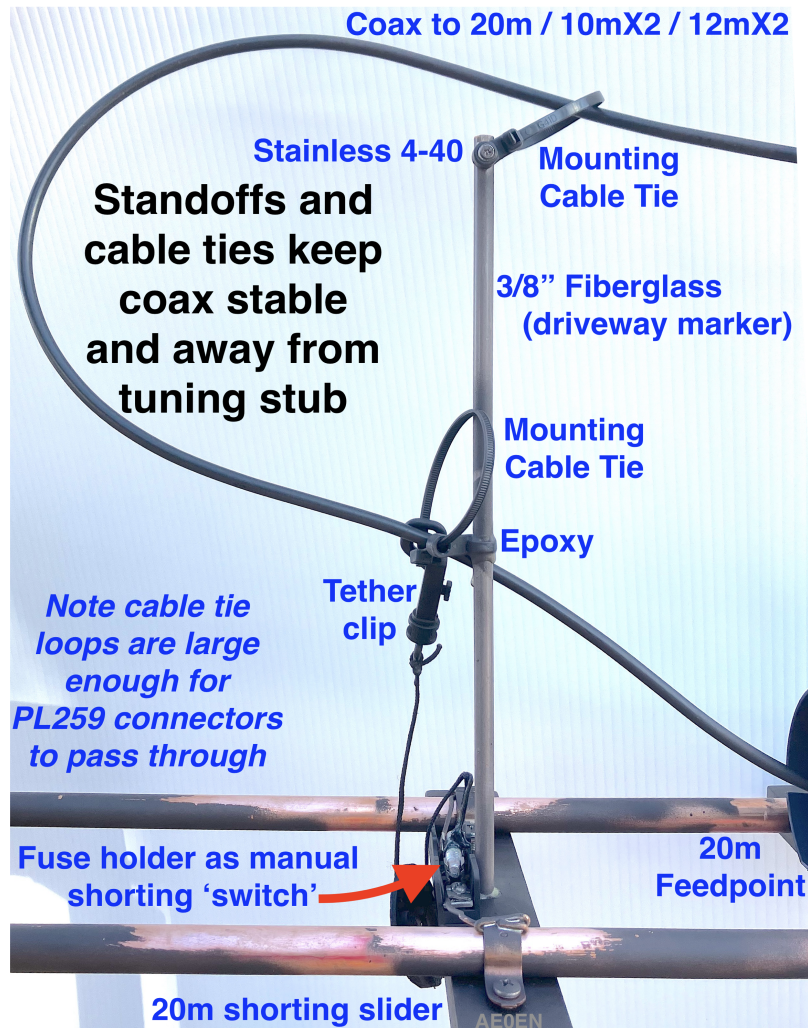


## Cable Standoffs:

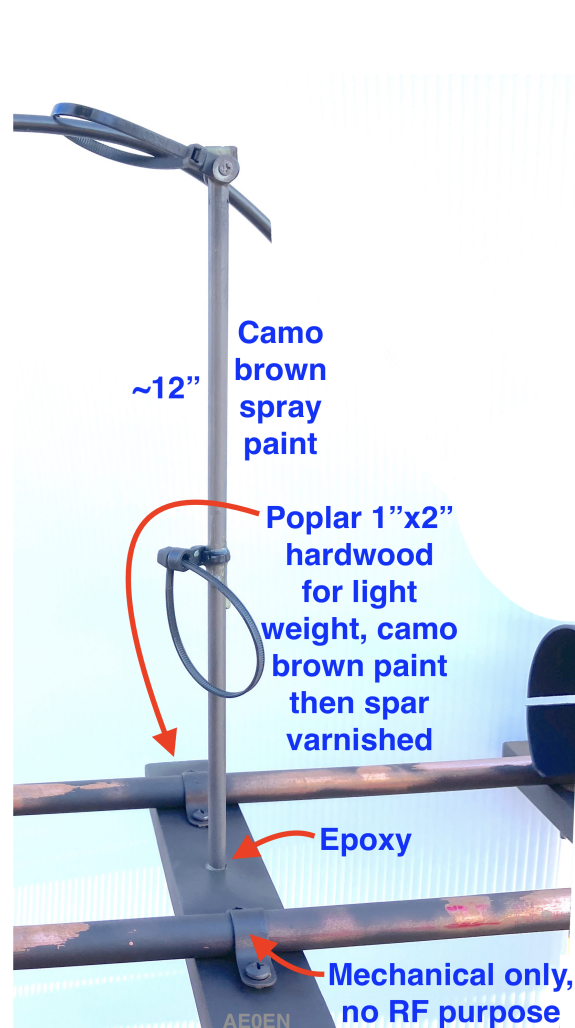
These 'cable standoffs' are made from 3/8" fiberglass driveway markers epoxied into either an actual tuning slider or their own 'dummy' slider, as shown on the next page. The simple loops are easily made using 'mountable cable ties' and a stainless #4-40 or M3 bolt, or even just another cable tie secured with some epoxy. This allows the post-balun feedpoint cable's PL-259 to be run

through the 2" loops to keep them in a stable position. Note the loops are larger than the PL-259 connector itself.

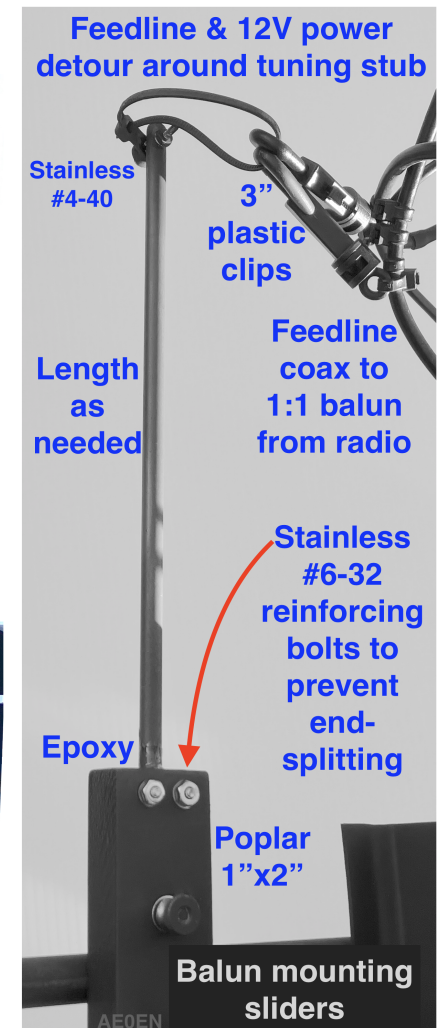
### Combo Shorting Slider and Standoff



### Standoff Only



### Lateral Standoff



(Above: Shorting 'switch' same as 'shorting bar' term used elsewhere).

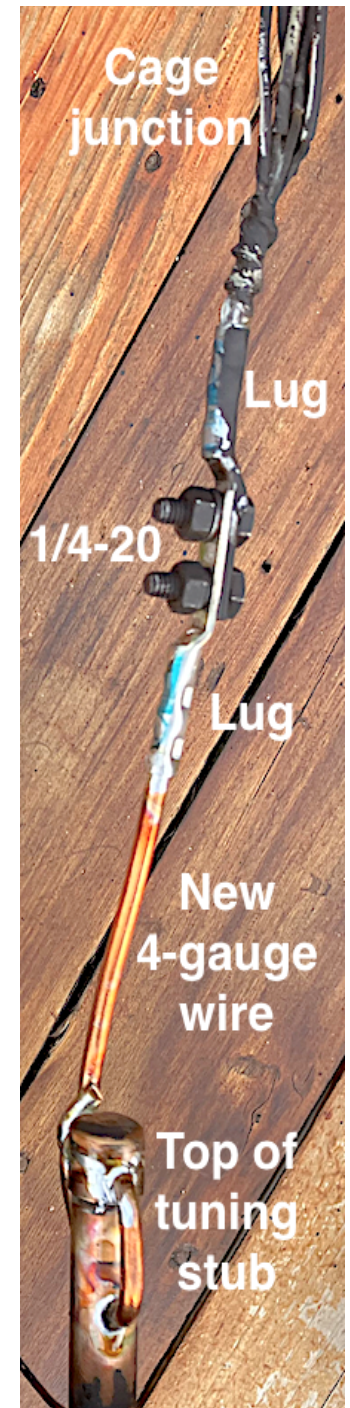
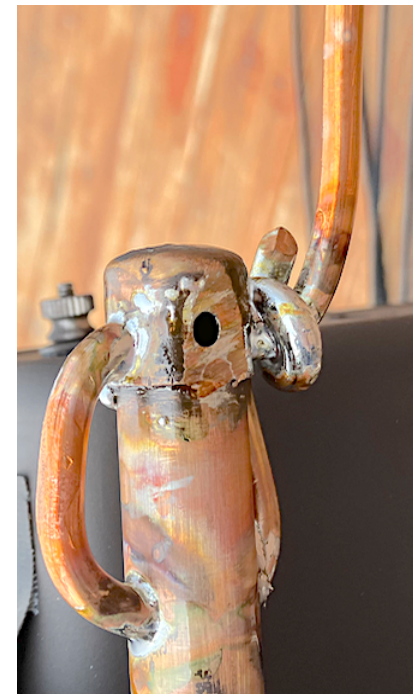
## Upgraded Lead Design:

The 19 lb weight of this '6-bander's tuning stub required an upgraded 5" lead wire design due to a fatigue failure. At center-right you can see the broken 10-gauge wire. The two-hole lugs that I use to connect major segments of the antenna (far right) can accommodate a maximum 4-gauge wire, so that was what I am using at present. 4-gauge wire is quite difficult to work with however, and both a short section of 'bending pipe' with a  $\sim\frac{1}{4}$ " hole and large Channel-locks (tongue and groove pliers) are needed to subdue it. First straightened it by hand and with a rubber mallet (see Chapter 17 'Photo Collage' 'A' & 'B'). The bending pipe is then placed over the wire and used to bend it with more-or-less tight right-angle corners (lower-center), and then the large pliers compress and force the wire into its final position. It is then soldered at all four holes with a butane pen torch. Because there are two wire paths through the  $\frac{1}{2}$ " copper pipe, those soldered junctions experience no twisting and should remain very solid RF connections. Any further fatigue issues will likely occur above the tuning stub's two-hole lug, near the junction of the six 12-gauge caging wires (far right), which will at least be easier to repair. I have been considering better designs to make a more robust and fatigue-resistant flexible connection at those six wires, but it is a materials and mechanical problem beyond my experience. In any event, the present solution should prove satisfactory for the foreseeable future – one incremental improvement at a time!

Because a broken lead at the top or at the tuning stub could potentially damage the antenna I have added 'backup' supports in the form of 1/8" black Dacron cordage loops (350 lbs cord strength). For example, in the tall photo at far right, this cordage (not shown) runs through the 4-gauge wire 'loop' at the top of the tuning stub up *into* the cage wire junction at the top of the photo. The same backup support technique is used at the top element copper pipe's lead to connect to the wire cage junction up there. These should carry the load should any of the four leads break.

## 6-Band Antenna weight:

Overall the antenna weighs about 25 lbs *as measured on the halyard line* – that includes rope and coax weight. The two 12' copper pipes and fittings contribute about 5 lbs to the total tuning stub weight of 19 lbs. Because they provide essential structural strength and rigidity, no obvious or inexpensive way to significantly reduce tuning stub weight is apparent. The sliders are of poplar wood for its light weight. The solution for this heavy tuning stub issue is presented on p106, "Cage Junction Mechanical Load Reduction."



## Better Feedpoint Slider:

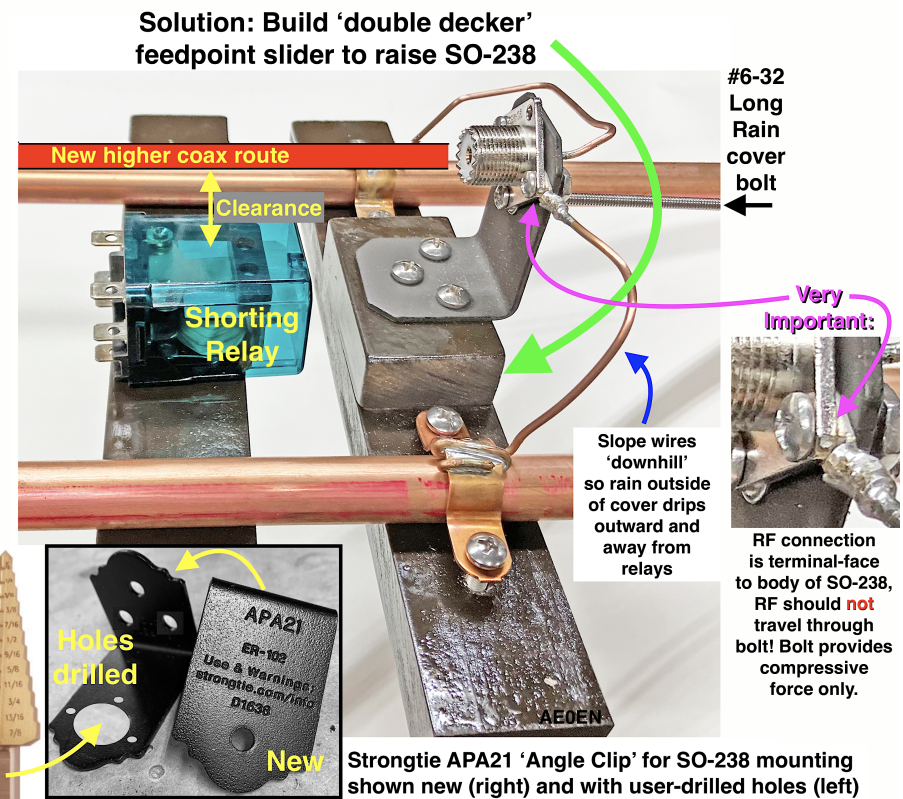
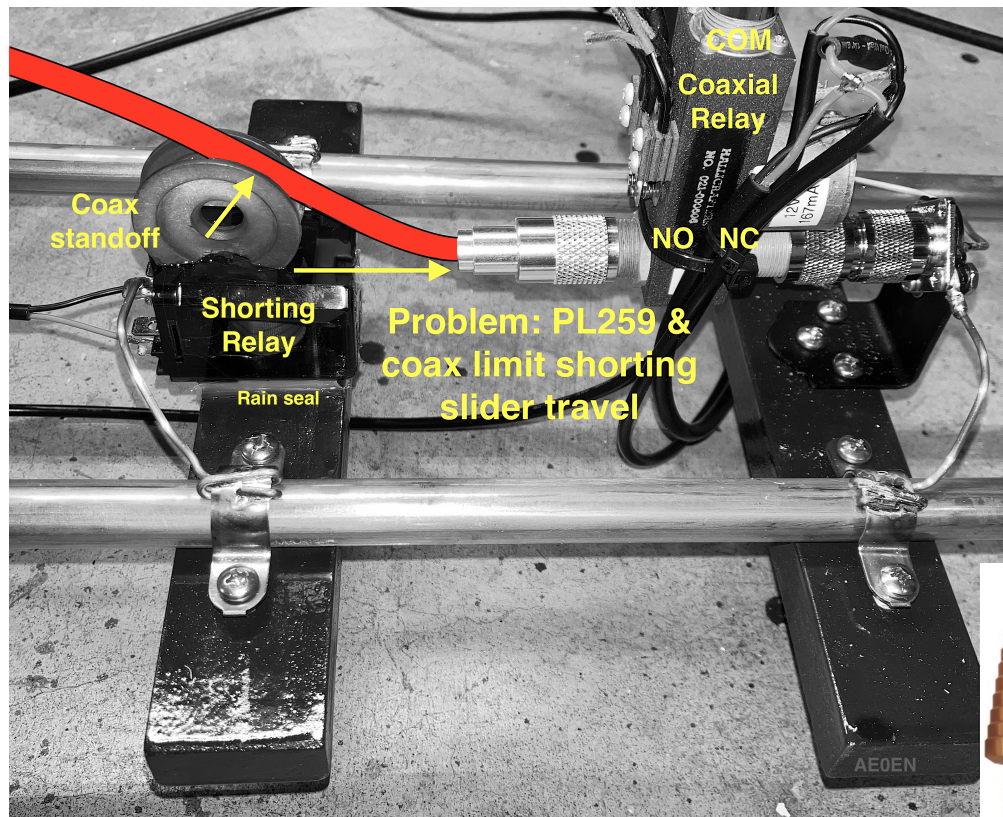
An incremental improvement created late in this project addressed the occasional need for a better slider-design, so that the coax route to the coaxial relay (shown in red below) is not be forced upward by the shorting relay approaching the coaxial relay. This doesn't happen often as the closest approach I have seen is about 6" (at 15m), yet I don't like seeing the coax stressed. The simple solution was to build a **'double decker' slider** (below, right) to raise the angle bracket and SO-238 by an additional  $\frac{3}{4}$ ". It works well, but this antenna was largely completed by the time this idea dawned on me, and so it uses the original single-height sliders for most of the relays. (By the way, the right side photo below is an early mockup, which is why the shorting slider is missing mounting straps, wiring, and connections to the relay.)

Some words of advice when drilling the 'angle clip' brackets for the SO-238 and mounting bolts: First, use a center punch to mark the hole locations, and second, you *must* hold the bracket with pliers of some kind when drilling it – as well as eye-protection, of course. I have had good luck with 'step bits' like the one shown below (bottom center) as they do not seem to seize the workpiece

the way large spiral bits do. I used *Strongtie APA21* brackets (1.5"x2") as they are strong and low cost, a mild steel of some kind, and can be drilled fairly easily. They come with just two holes so you will need to drill several more. **Stainless steel angle clips would be better**, but I haven't located a source.

There is an important note below (far right inset) about the crimped terminal lug **face** *directly contacting* the **body** of the SO-238. It is an unwise practice to route RF or even DC *through* a steel bolt. The purpose of the bolt is to forcefully compress the two (or more) surfaces of the connection.

The shorting relays are packaged in a nearly waterproof blue plastic shell. I add a narrow  $\frac{1}{2}$ " 'skirt' of partly folded-over duct tape around the bottom terminal perimeter as a 'drip edge'. I also seal the three sides of the shell contacting the wood slider with silicon to keep water out. The vacant terminal 'slits' in the base act as 'weep holes' so that condensation and humidity can escape. (It is always best to have at least *two* weep holes on the underside of a small outdoor enclosure, as far apart as is practical. Larger enclosures should have more holes.)

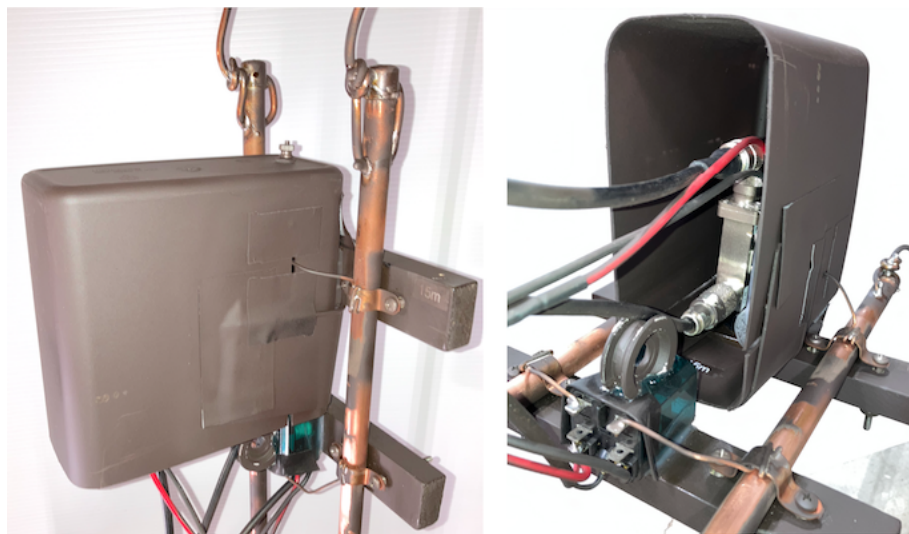


## Rain Hoods:

The 'rain hoods' or 'rain covers' for the manually connected, non-relay SO-238s are made from inexpensive plastic drinking glasses, with slots cut up the sides for the wire and one large notch cut in the back for the angle clip bracket. Choose wide-mouth glasses so you can reach into them and connect or disconnect the PL-259 there. Note one of the SO-239's 6-32 bolts is 3" long, to secure the plastic glass in place via a knurled nut and a rubber washer.



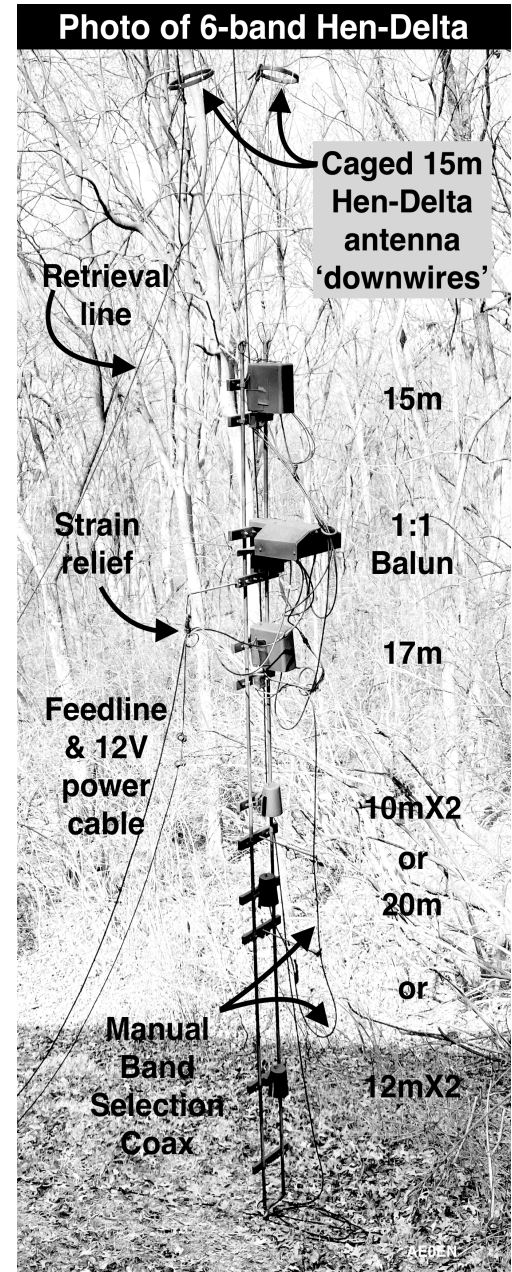
The coaxial relays were more difficult to cover, but I did find an inexpensive cereal container (center right) at Walmart with the appropriate dimensions. It was shortened with metal shears, slots were cut in the sides for the wires, and a wide notch was cut in the rear to slide over the angle clip bracket. When completed it was secured in place, the slots were taped, and everything was painted.



The bottom opening is large enough to reach into and connect or disconnect a PL-259. I have wondered if some kind of waterproof, velcro-sealed, soft-sided camping storage 'bag' might be easier and better, but to date I have not found anything like that.

## Photo of 6-band Hen-Delta:

At right is a photo of the 6-band antenna lowered to the ground for tuning tweaks. Since the tuning stub is 12' long, it has to be lowered to the point of tipping over 60° to reach the top band. The tuning stub weights 19 lbs and the upper portion of the antenna adds another 6 lbs, for a total of about 25 lb.



# QRZ Logbook of first 4 days of 6-band Hen-Delta Testing

All QSOs at 100W except as noted. Callsigns truncated for privacy

| #  | Date       | Time  | RX Call | TX Fre... | RX Mode | RX Grid | RX Country            |
|----|------------|-------|---------|-----------|---------|---------|-----------------------|
| 1  | 2025-03-02 | 20:11 | XE1     | 28.500    | SSB     | DL9lee  | Mexico                |
| 2  | 2025-03-02 | 20:01 | D4K     | 28.434    | SSB     | HK76mu  | Cape Verde            |
| 3  | 2025-03-02 | 19:53 | CR3     | 28.254    | SSB     | IM12nr  | Portugal              |
| 4  | 2025-03-02 | 01:12 | J75     | 21.328    | SSB     | FK96aa  | Dominica              |
| 5  | 2025-03-02 | 01:01 | PW2     | 28.546    | SSB     | GH49eq  | Brazil                |
| 6  | 2025-03-02 | 00:56 | LT7     | 28.547    | SSB     | GG10kh  | Argentina             |
| 7  | 2025-03-02 | 00:51 | YE9     | 28.627    | SSB     | OI71qv  | Indonesia <b>600W</b> |
| 8  | 2025-03-02 | 00:32 | W7J     | 18.145    | SSB     | DM33tq  | United States         |
| 9  | 2025-03-01 | 23:18 | ZF1     | 28.302    | SSB     | EK99ig  | Cayman Islands        |
| 10 | 2025-03-01 | 23:11 | PW2     | 28.670    | SSB     | GH49eq  | Brazil                |
| 11 | 2025-03-01 | 23:09 | PY2     | 28.640    | SSB     | GG66il  | Brazil                |
| 12 | 2025-03-01 | 22:58 | HC8     | 28.509    | SSB     | EI49kd  | Galapagos Isl...      |
| 13 | 2025-03-01 | 22:53 | XE1     | 28.469    | SSB     | EK09ji  | Mexico                |
| 14 | 2025-03-01 | 22:48 | LU3     | 28.451    | SSB     | GF15ab  | Argentina             |
| 15 | 2025-03-01 | 22:33 | HJ4     | 28.362    | SSB     | FJ26ef  | Colombia              |
| 16 | 2025-03-01 | 22:01 | EA5     | 21.355    | SSB     | IM99ul  | Spain                 |
| 17 | 2025-03-01 | 21:59 | CQ8     | 21.328    | SSB     | HM68jr  | Azores                |
| 18 | 2025-03-01 | 21:45 | PX2     | 21.312    | SSB     | GG66se  | Brazil                |
| 19 | 2025-03-01 | 21:43 | J62     | 21.304    | SSB     | FK93mv  | St Lucia              |
| 20 | 2025-03-01 | 21:35 | TI5     | 21.287    | SSB     | EK70wf  | Costa Rica            |
| 21 | 2025-03-01 | 21:32 | PJ4     | 21.284    | SSB     | FK52ud  | Bonaire               |
| 22 | 2025-03-01 | 21:26 | P49     | 21.268    | SSB     | FK52ak  | Aruba                 |
| 23 | 2025-03-01 | 21:23 | IQ9     | 21.261    | SSB     | JM76hu  | Italy                 |
| 24 | 2025-03-01 | 21:20 | HI3     | 21.255    | SSB     | FK49tl  | Dominican Re...       |
| 25 | 2025-03-01 | 21:14 | HK1     | 21.243    | SSB     | FK21oa  | Colombia              |

| #  | Date       | Time  | RX Call | TX Fre... | RX Mode | RX Grid | RX Country     |
|----|------------|-------|---------|-----------|---------|---------|----------------|
| 26 | 2025-03-01 | 21:04 | HI3I    | 21.233    | SSB     | FK48ws  | Dominican Re.  |
| 27 | 2025-03-01 | 20:54 | AA4S    | 18.147    | SSB     | FM07ab  | United States  |
| 28 | 2025-03-01 | 20:53 | W6I     | 18.147    | SSB     | FM07ce  | United States  |
| 29 | 2025-03-01 | 20:44 | KA5     | 18.136    | SSB     | EL29fv  | United States  |
| 30 | 2025-03-01 | 20:43 | KC2E    | 18.136    | SSB     | EL29fv  | United States  |
| 31 | 2025-02-27 | 16:09 | VO1     | 24.953    | SSB     | FN04jm  | Canada         |
| 32 | 2025-02-27 | 15:56 | WX4V    | 24.933    | SSB     | FM15bk  | United States  |
| 33 | 2025-02-27 | 15:52 | K4ZF    | 24.944    | SSB     | EL98er  | United States  |
| 34 | 2025-02-27 | 15:36 | NV4E    | 18.150    | SSB     | EL86ux  | United States  |
| 35 | 2025-02-27 | 14:17 | WP4L    | 21.255    | SSB     | FK68wg  | Puerto Rico    |
| 36 | 2025-02-27 | 14:11 | PJ2     | 21.285    | SSB     | FK52md  | Curacao        |
| 37 | 2025-02-27 | 14:06 | MW0C    | 21.308    | SSB     | IO81cn  | Wales          |
| 38 | 2025-02-27 | 14:00 | N1W     | 21.332    | SSB     | FN31rm  | United States  |
| 39 | 2025-02-27 | 13:38 | W0ME    | 18.134    | SSB     | EL88ps  | United States  |
| 40 | 2025-02-27 | 13:10 | VP2E    | 21.290    | SSB     | FK88lf  | Anguilla       |
| 41 | 2025-02-27 | 00:10 | PJ2     | 21.300    | SSB     |         | Curacao        |
| 42 | 2025-02-27 | 00:04 | CT9     | 21.315    | SSB     |         | Madeira Island |
| 43 | 2025-02-26 | 23:50 | YV5J    | 24.950    | SSB     | FK60nj  | Venezuela      |
| 44 | 2025-02-26 | 23:42 | VA7E    | 24.957    | SSB     | CN89mg  | Canada         |
| 45 | 2025-02-26 | 23:06 | KM0C    | 14.237    | SSB     | EN16wg  | United States  |
| 46 | 2025-02-26 | 22:57 | K2BF    | 14.276    | SSB     | EN34it  | United States  |
| 47 | 2025-02-26 | 22:52 | KN4I    | 14.236    | SSB     | EM74xe  | United States  |
| 48 | 2025-02-26 | 22:33 | LU1I    | 28.458    | SSB     | GF05    | Argentina      |
| 49 | 2025-02-26 | 22:27 | CA3E    | 28.510    | SSB     | FF46rl  | Chile          |
| 50 | 2025-02-26 | 22:08 | J62E    | 18.120    | SSB     | FK93mv  | St Lucia       |

This QRZ logbook page shows the first 50 QSOs during the first four days of antenna use as subjective proof of 6-band functionality (except 6m which I'll try another time). The antenna provides reception about 1 S-unit stronger

than its little brother – a 10m primary/12m secondary Hen-Delta – but this may be in part due to the larger antenna being at ~55' above ground vs ~40' for the smaller antenna, and therefore having a lower take-off angle. Or it may be due

## Screen Captures of IC-7300 spectrum during busy periods to illustrate 6-band Hen-Delta reception strength



to the antenna having twice the area of the 10m's – remember there are two wavelengths of 10m at the '10mX2' tuning stub point. Perhaps in the future someone may do an extensive computer simulations of these antennas to advance the understand of the many aspects of their performance.

The IC-7300 screen captures above illustrate anecdotally the 6-band antenna's reception performance during the March 1, 2025 weekend's DX contest (except 6m). The lower 10m image was taken using the older, smaller 10m/12m Hen-Delta that I have two of years experience with. I have worked considerable DX

with it. The very nice performance of the *higher-above-ground* 6-band antenna, and the convenience of having switch-selectable bands, may yet induce me to purchase two additional coaxial relays for it in the future...

### Each Band has it's Own Take-Off Angle:

Take-off angle is a function of height above ground *in wavelengths*, so as you select longer wavelength bands you also choose a slightly higher take-off angle, and thus a shorter range skip path. The 10m-20m bands span 1.6 to 0.8 wavelengths above ground at 55'. If I wished, I could lower the antenna's halyard line and dramatically increase all of the take-off angles for shorter range communication.

### 'Free' 6mX3 Band:

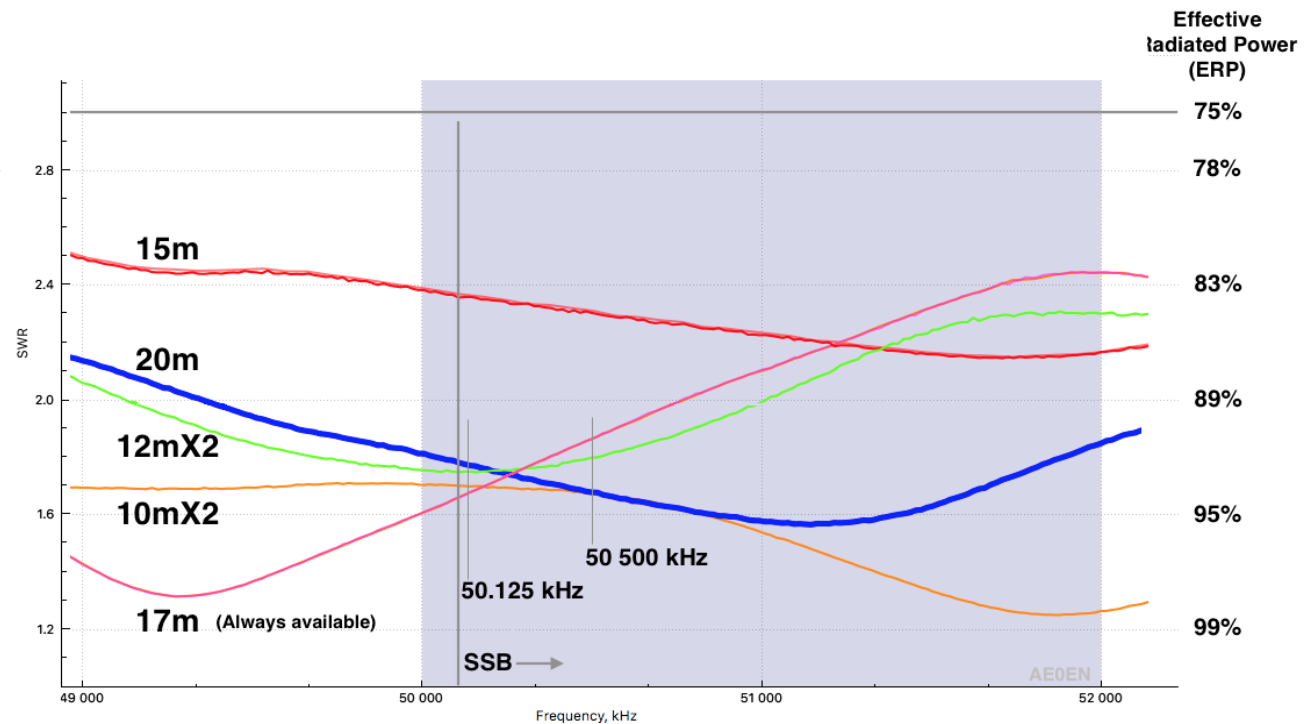
Investigating the 6mX3 band more extensively proved interesting. All of the tunable bands (those with their own tuning stub sliders) have a more-or-less useable resonance at 6m.

17m is likely the best option for 6mX3 SSB under about 50,300 kHz (50,125 kHz is the 'calling frequency' in the USA) with an SWR near 1.7, which results in an effective radiated power (ERP) of about 93%. 17m is also a *permanent* band, and is thus always available for 6mX3 just by selecting the 17m switch position and then tuning the radio to the 6m band.

15M is also a permanent band, but its 6m SWR curve is much higher (see graph above). 20M, 10mX2 and 12mX2 are manually selected by coax position and might be inconveniently configured at the rare 'magic moment' that 6m happened to be open.

Keep in mind that *all* the curves shown here are for *my* antenna *as of this tuning*. With a 'free' resonance of other bands, any tuning change elsewhere will alter these curves, sometimes significantly. For example, after recent tuning tweaks the 6m curve on the 10mX2 band happens to be much lower (and better) than shown above (see p108). For that reason the 6m SWR needs to be reconfirmed after other tuning adjustments, periodically, or just tuned 'live' at need.

## 'Free' 6mX3 SWR Curves for Each Band



For someone not especially interested in 'the magic' (and rarely open) 6m band, this 'free band' happenstance is a perfect solution, but those with strong 6m interests could add a dedicated pair of tuning sliders and obtain a much nicer, permanent 6m SWR.

2025-0524 6m update: As shown on p101 above, I found the 6m band 'open' this evening and was able to confirm that 6mX3 was viable as expected, working New Jersey, North Carolina, and South Carolina on SSB. One amateur described the band condition as 'weak sporadic', and I found trying to work it reminiscent of 'whack-a-mole'! By the time I could tune a strong signal on the IC-7300 spectrum screen and hear a reply to my call, they would disappear! Signal strength would be 59+10 one minute and gone the next! But one of my QSOs lasted a satisfying five minutes before fading. Such is life on 6m!

2025-0615 6m update: Very busy contest today and the band was open for many hours. I updated the 6m screen capture to show the contest traffic.

2025-0703 6m open: Worked Boston 1042 miles, NM 769 miles, CO 787 miles.

|   | Construction dimensions for MONO-BAND Hen-Delta antennas.  |               |          |         |               |               |          |               |        |               |               |
|---|--|---------------|----------|---------|---------------|---------------|----------|---------------|--------|---------------|---------------|
| Band  | 70cm UHF   | 2m VHF        | 6m HF    | 10m HF  | 11m CB        | 12m HF        | 15m HF   | 17m HF        | 20m HF | 40m HF        | 80m HF        |
| Center Frequency (MHz)                                    | 435  | 146           | 52       | 28.5    | 27.2          | 24.94         | 21.225   | 18.118        | 14.175 | 7.150         | 3.75          |
|   |  |               |          |         |               |               |          |               |        |               |               |
| All dimensions in INCHES                                  | The following dimensions will VARY depending on materials and cage diameter. Dimensions in RED have actually been built.   |               |          |         |               |               |          |               |        |               |               |
| 'Built' status  | Not attempted  | Not attempted | Original | Built   | Not attempted | Not attempted | Built    | Not attempted | Built  | Not attempted | Not attempted |
| Top copper pipe element length                            | 3.94   | 11.75         | 33       | 59      | 62            | 67            | 77.5     | 91            | 116    | 230           | 438           |
| Downwire side height                                      | 12.0   | 35.6          | 100      | 180     | 189           | 206           | 198      | 232           | 361    | 716           | 1,365         |
| Caging diameter actually built                            |  |               | 0.625    | 3.5 ABS |               |               | 6.25 ABS |               | 1.1    |               |               |
| Caging diameter at 1% of wavelength                       | 0.28   | 0.82          | 2.3      | 4.2     | 4.4           | 4.8           | 5.7      | 6.6           | 8.5    | 17            | 32            |
| Caging diameter at max 2% of wavelength                   | 0.55   | 1.6           | 4.6      | 8.4     | 8.8           | 9.6           | 11.3     | 13.2          | 16.9   | 33.6          | 64.0          |
|   |  |               |          |         |               |               |          |               |        |               |               |
| Tuning stub nominal copper pipe size                      | 12gauge-0.25"  | 12gauge-0.5"  | 0.5"     | 0.5"    | 0.5"          | 0.5"          | 0.5"     | 0.5"          | 0.5"   | 0.5"          | 0.5"          |
| Tuning stub height (longer okay, can be shortened later)* | 2"   | 6"            | 18"      | 30"     | 30"           | 30"           | 40"      | 40"           | 60"    | 96" (?)       | 120" (?)      |
| Tuning stub pipe separation, center-to-center             | 0.36"  | 1"-2"         | 3.125"   | 5"      | 5"            | 5"            | 5"       | 5"            | 5"     | 5" (?)        | 5" (?)        |
|   |  |               |          |         |               |               |          |               |        |               |               |
|   | *Final tuning slider positions depend on downwire length, materials used, and caging, so tuning stub height given is generous to minimize trimming or extending of downwires.  |               |          |         |               |               |          |               |        |               |               |
|   | Tuning stub copper pipe may be shortened when antenna is operational, but always leave an 'ample' amount of space below the bottom shorting slider to accommodate future antenna re-tuning or antenna modification. A LONGER TUNING STUB ALLOWS ADDITIONAL NEARBY BANDS TO BE ADDED LATER. |               |          |         |               |               |          |               |        |               |               |

‘Downwire’ entries in **black** are extrapolated from nearby **built** dimensions, are cage diameter dependent and thus approximate.

## Construction Dimensions for Mono-Band Hen-Delta’s:

If you plan ahead you can start with a monoband Hen-Delta and add additional bands later. These may be longer wavelength bands or multiples of shorter wavelength bands. For example, as an experiment I replaced the short tuning stub on my 10m antenna with one that was 60” tall. That allowed me to add the 12m and 6mX2 bands. I could also have added the 11m CB band. An even longer tuning stub would have allowed 15m.

You could probably add a 2mX3 tuning point on a 6m-primary Hen-Delta (polarity considerations aside) provided the 1:1 balun or common mode choke was rated for VHF frequencies – 2mX3 might even be resonant on the 6m feed-point. You could probably build a VHF/UHF Hen-Delta with a single feed-point, but I have not yet attempted this because my *RigExpert 230 Zoom* is limited to 230MHz.

Just remember that there is no ‘free lunch’ as you add bands further and further down the tuning stub you accept modest losses because the tuning stub does not contribute to the antenna area. A wild guess would be a fraction of a 1 db for each longer single-wavelength band. The performance of multiple-wavelength tuning points, like 10mX2, is unknown but likely similar. **Fortunately, in practical terms, these losses may in fact not be discernible.**

The 5” leads at the top of the HF tuning stub leads are not included in the above calculations. They may be considered as part of the ‘downwire’ length. In VHF or higher frequency Hen-Deltas the builder may wish to shorten those leads or directly attach them to a flattened section of pipe. I recommend two-hole lugs to prevent the connection from eventually loosening due to antenna sway – I’ve seen that happen, which is why I only use two-hole lugs!

Some very wide bands are primarily utilized in their lower frequency range for digital, CW, or lower SSB. In the table above 10m was centered on 28,500 kHz and not 28,850 kHz for this reason. You may wish to tweak the above dimensions to account for your preference relative to the center frequency used in the table. That said, the **caged** Hen-Delta offers a very wide bandwidth and is easily tuned to whatever portion of the band is of most interest.

Note: The 20m antenna shown in the table above used a smaller than optimal cage diameter of 1.1” – it was simply another step in caging experimentation. That antenna has been decommissioned and its materials repurposed. The suggested 1%–2% diameter values would provide a broader SWR curve.

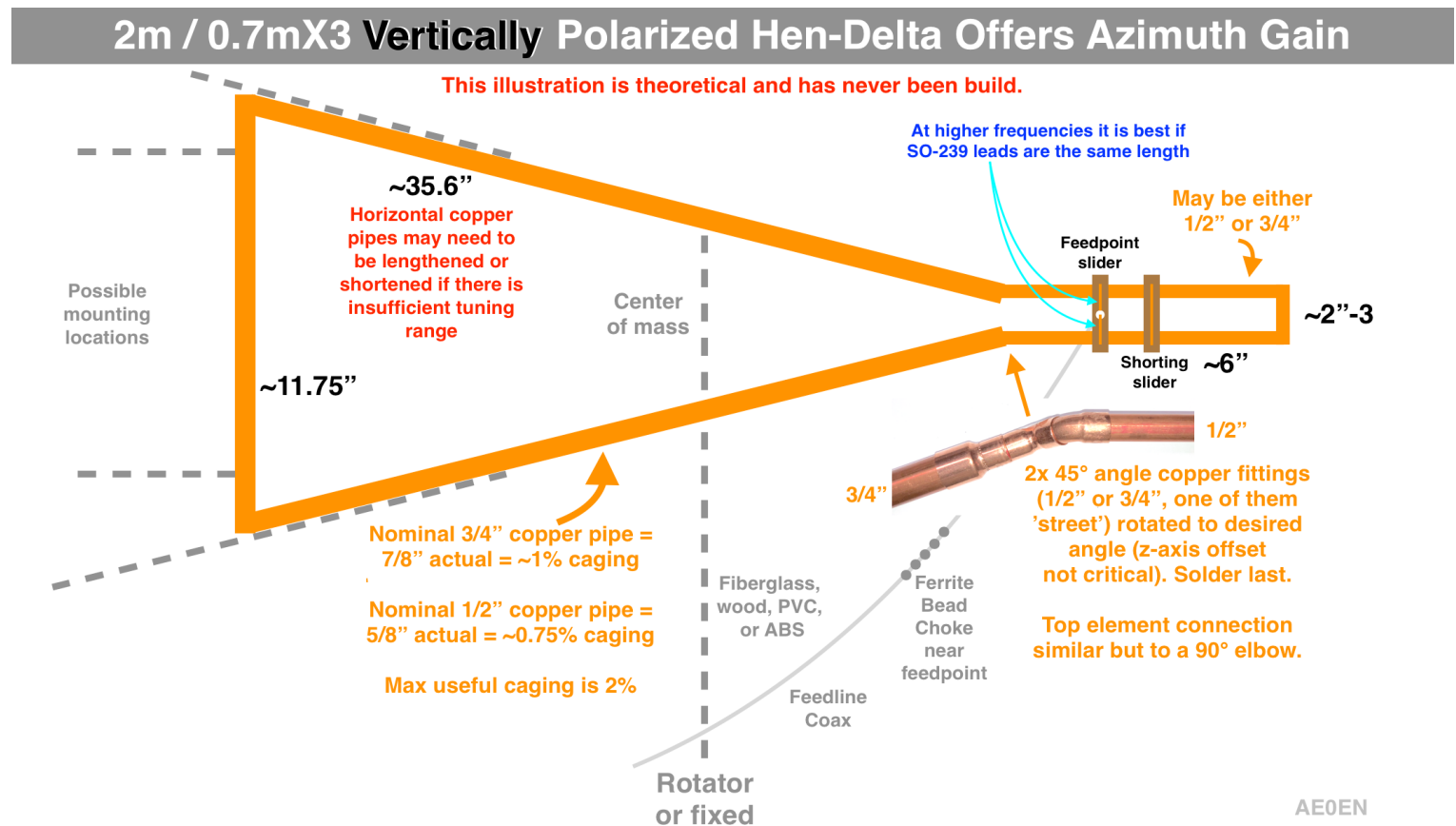
## VHF/UHF Vertically Polarized Hen-Delta with Azimuth Gain:

I thought I would touch on these short wavelength bands for the sake of completeness, but do understand that ***I have not built one***. Like its predecessor, the *Hentenna*, the Hen-Delta emits polarized RF at 90° to its major axis (as all ‘skeleton-slot’ antennas do), so for those needed vertically polarized RF for local *line-of-sight* communications, the Hen-Delta must be mounted on its side. To the best of my knowledge it retains all of its other fine qualities, including modest gain similar to 2- or 3-element yagis, but with much broader bandwidth (yagis are known for having narrow bandwidth). While this illustration shows solid copper pipe for all elements for simplicity of construction and mechanical strength, it could also be constructed with caged wires as a more lightweight and collapsible antenna. It is a purely mechanical issue. It could also be suspended via an inverted-V rope from the far left and far right high points.

I have wondered if some variation of this design might be suitable for satellite use, since it should be operable simultaneously on both VHF and UHF bands. I have no experience tracking satellites with an alt-azimuth drive, but if a *Hentenna* has ever been used for this purpose then the Hen-Delta should perform similarly.

Theoretically 2m should be available as a multiple wavelength band on my 6-band Hen-Delta, but my 1:1 current balun isn’t rated higher than 6m (50MHz). And it would be horizontally polarized whereas local 2m use is vertically polarized. I do have a home-made, omnidirectional ‘Slim Jim’ for 2m made from 450 ohm window line, but to date I have limited interest in line-of-sight bands.

**SO-239 Lead Length:** Note that when building any Hen-Delta antenna – but especially for higher frequencies – it is ‘best practice’ to make both SO-239 leads to the tuning stub the same functional path length (which includes allowing for redundant two-point SO-239 ground connections, if used). This will likely require that you bend both leads smoothly in the stub- or Z-axis. Excess lead length is not a problem because it simply means that the feedpoint slider will be shifted slightly closer to the antenna during tuning. The highly adaptable Hen-Delta tuning stub easily absorbs any dimensional variations during tuning as long as the antenna is built as symmetrically as practical. Hypothetically, one could imagine tilting the tuning sliders (or deliberately lengthening only one lead) to compensate for any structural asymmetry during building, but I have never needed to do so. Such precision would only be necessary if you insisted upon tuning to an SWR of 1.000, for example.



## Homemade Capstan Drive:

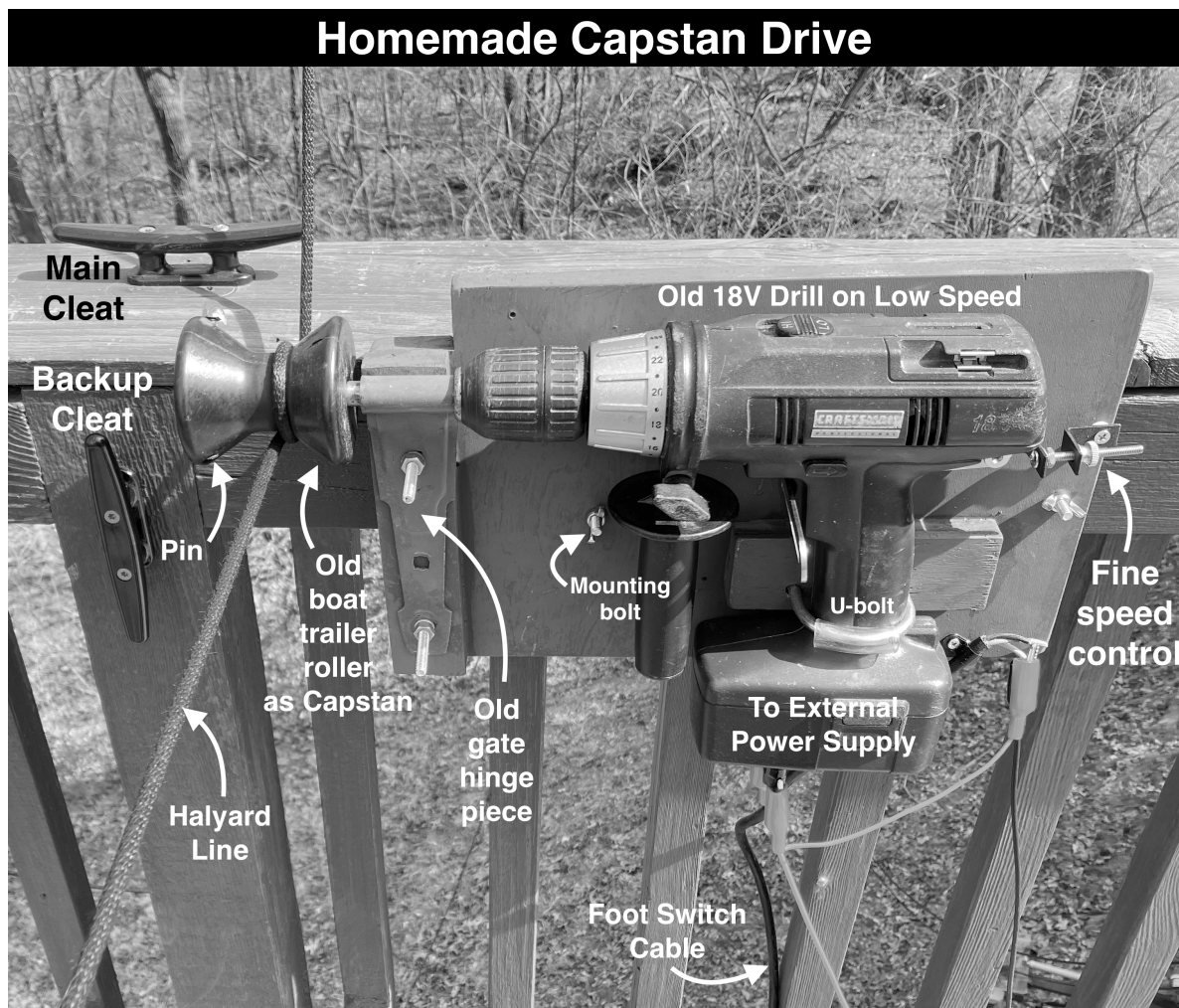
March 9, 2025: There are still a few refinements to add to this capstan drive, but it is quite functional as shown. It is only used to raise the antenna, the cleats themselves allow it to be easily lowered.

The 25lb antenna load is trivial for the ¼" Dacron line to handle – it's rated for 980 lbs – but it is thin enough to be difficult for even more youthful hands than mine to grip and hoist – even with gloves! Tuning a 6-band antenna requires raising and lowering it once per tuning cycle (you can sometimes tweak 3 bands at a time) which is a tiring enough process as is!

Even a used sailing capstan drive is well over \$800 – over \$1200 new – so I decided to try to build one with this retired 1995 era, battery-less drill and a hard rubber sailboat trailer roller from my junk drawer. I used a small lab power supply to provide the constant 18V at ~4.5A via a foot switch, leaving both hands free to wrangle the line (note: supplying too low a voltage to a DC brush-type motor will burn it out). The variable speed setting control was tricky, but an L-bracket, a long 10-32 bolt, and brass knurled nut worked well. A speed of about 70 RPM will raise the antenna effortlessly from the ground in under a minute, allowing time to make certain the steering lines don't get hung up on anything as they lift into position. It *could* be run much faster but that really isn't necessary. Small blue cable ties on the incoming halyard line (not shown) serve as 'a flag' to alert the operator that the antenna is at full height.

When the antenna is at operating height the halyard line is carefully removed from the capstan and transferred to both cleats – a desirable redundancy because sometimes nylon cleats fail without warning, and seeing my antenna plummet to the ground is a trauma I prefer to avoid! When the line has been transferred to the cleats it allows the entire capstan drive to be removed from the railing – it's now mounted with fast spinning thumb wheels (much nicer than wingnuts) – and taken indoors, as it is not weatherproof and would be difficult to replace.

This capstan drive has proven very useful and a joy to use. David AE0IZ has



donated an old 170W notebook computer's power supply 'brick' to power it. I have also added a polycarbonate rain cover to protect the motor from an unexpected shower.

Important note: For simple ground-based rotators such as mine it is best if the main cleat (above photo), the pulley in the tree, and the center of the rotator are all in the same vertical plane. This allows 180° antenna rotation before the moving steering lines encounter either the fixed halyard line *or* either of the rotating caged downwires of the antenna. Since the antenna is bidirectional this allows coverage of all compass headings.

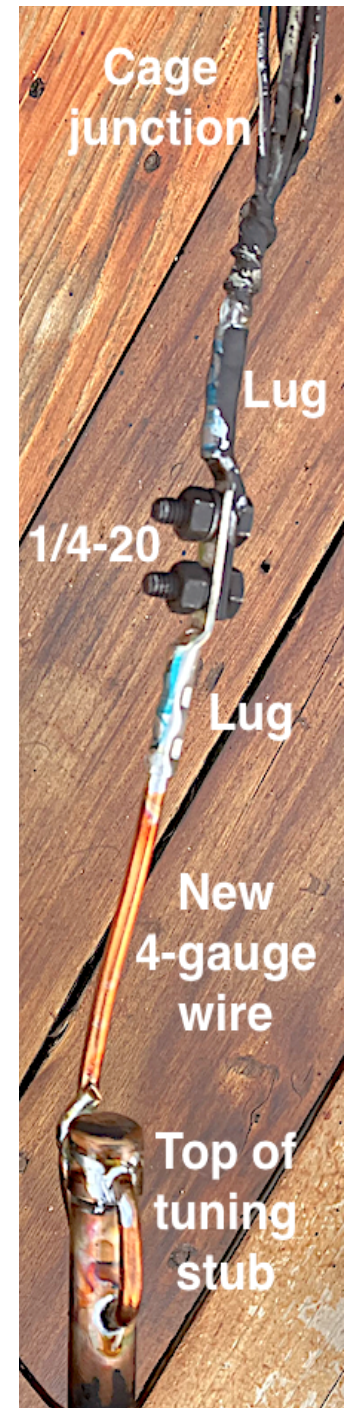
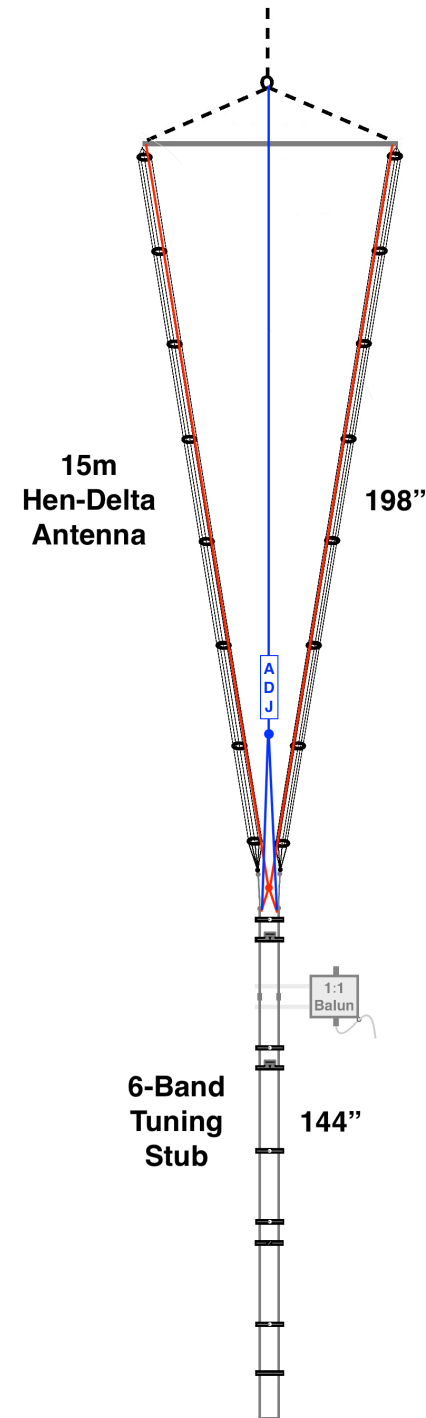
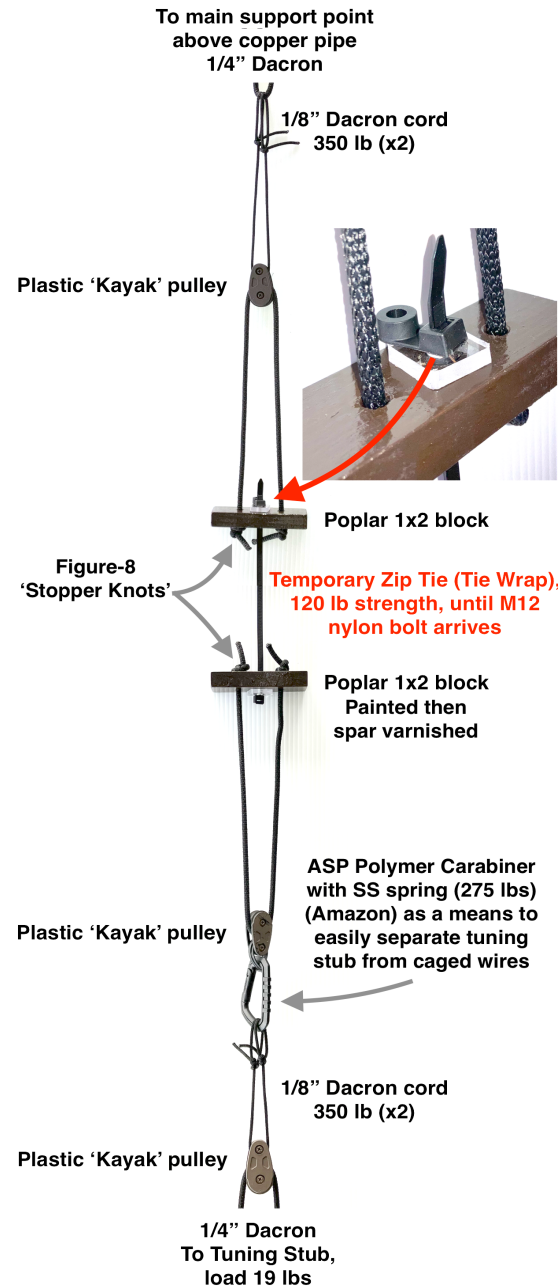
## Cage Junction Mechanical Load Reduction:

March-April 2025: I have been concerned about the increased weight of the tuning stub – now 19 lbs – on all four of the cage junction points (two at the top and two at the bottom). Each ‘downwire’ side carries about 10 lbs or about 1.5 lb per 12-gauge wire. That load may be sufficient to cause the wires to stretch over time. Worse, the wires must constantly flex slightly as the downwires and tuning stub sway in the wind with different motions. This will eventually result in the 12-gauge cage wires breaking near their soldered junction point (see far right at top) – a non-issue with the much lighter one- or two-band Hen-Delta tuning stubs.

There are two obvious solutions to reduce the load on these connections:

The first is shown by the **red lines** (1/4" Dacron rope) just inside the caged downwires (center right). These would connect the top copper element *directly* to the top of the tuning stub by way of a nonmetallic ‘turnbuckle equivalent’ (see ‘close-up’ at right), bypassing the cage wires and junctions with respect to carrying load. The ‘turnbuckle’ (a black nylon M12 x 200mm bolt from eBay, 5+ week delivery as this is written) would be carefully tensioned so that each downwire side would not quite go slack and still carry a pound or so of load to keep them straight. The tensioned rope inside the rings, carrying 90% of the load, would also help keep them in position. This tensioning mechanism has almost no metal – just two 1/2" stainless bolts in each plastic ‘kayak’ pulley. The pulleys may not be strictly necessary but I was trying to avoid non-axial loading of the M12 nylon bolt. However, it is so strong that it likely wouldn’t

### Tension Adjustment Close-up



matter, unless there was cold weather fatigue risk?

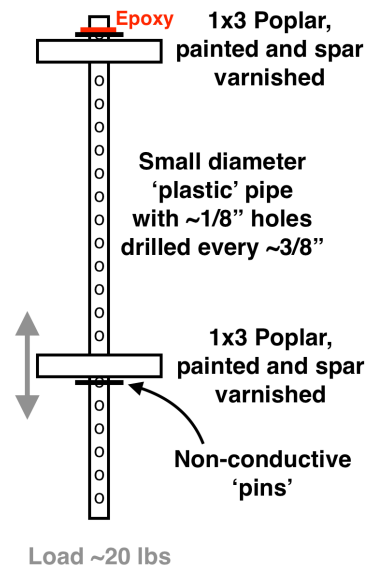
The second possible solution is simpler and is shown by the **vertical blue line** (¼" Dacron rope, prior page center right). This line attaches to the main support point above the antenna and runs down to the nonmetallic 'turnbuckle equivalent' (marked 'ADJ' for 'adjust'). Using the topmost support loop has the advantage of greatly reducing the compressive load on the ½" copper pipe (top element), and **this is what I have built and successfully tested**.

Below the 'turnbuckle' is a plastic pulley (see Chapter 25) supporting an inverted-V rope to the top of the tuning stub. The pulley allows the loads on each side of the inverted-V to equalize. The rope's tuning stub connection point in either solution would be the 4-gauge wires in the copper pipe (see far right, bottom) which are immovable strong. As before, the turnbuckle is tightened until the caged downwires show a reduction in tension – which is quite difficult to perceive unless you have a long pole with which to snag and deflect the caged wires and the blue central rope, and thereby thus estimate their relative tension. This initial tension may ease off slightly over the first few weeks as the knots tighten and the Dacron rope (while *relatively* inelastic) stretches slightly. I plan to recheck the tension if/when my M12 x 200mm nylon bolts arrive and are installed – I am temporarily substituting a thick, 175 lb tie-wrap (I suggest two for redundancy), as shown on the prior page. Note 'releasable' tie-wraps (zip-ties) are available. Or consider an alternative tensioning mechanism such as shown here, or invent your own. Small metal objects usually don't effect tuning noticeably, but try to avoid them as 'best practice'.

Either the red or blue solution should reduce the load on the four cage junctions by an order of magnitude and extend their service life by a similar factor.

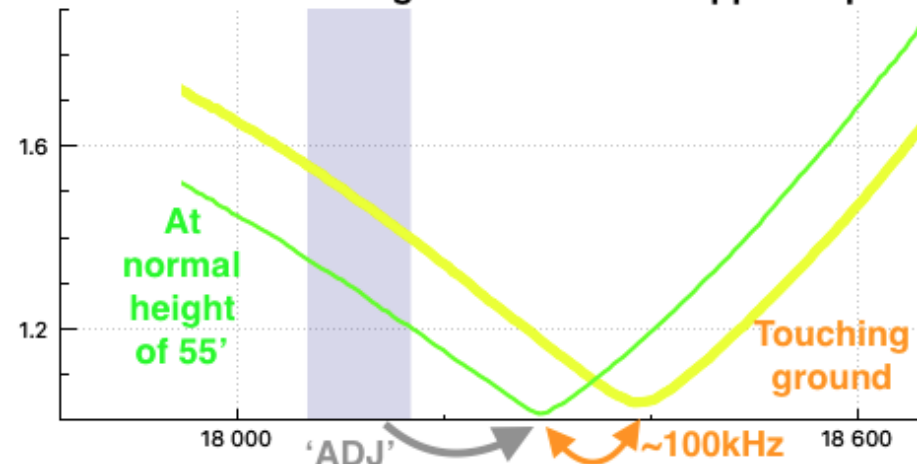
Note that in slightly altering the downwire tension – and thus the *shape* of the Hen-Delta – minor tuning tweaks may be necessary for some bands. For my an-

#### Alternative Adjustment Mechanism vs Nylon M12 bolt



tenna the 15m, 20m, and 10mX2 were unchanged, but the 17m sliders needed to be moved a half-inch downward on the tuning stub to lower the frequency.

#### Frequency Shift vs Height Above Ground Noted when re-tuning 17m with blue support rope



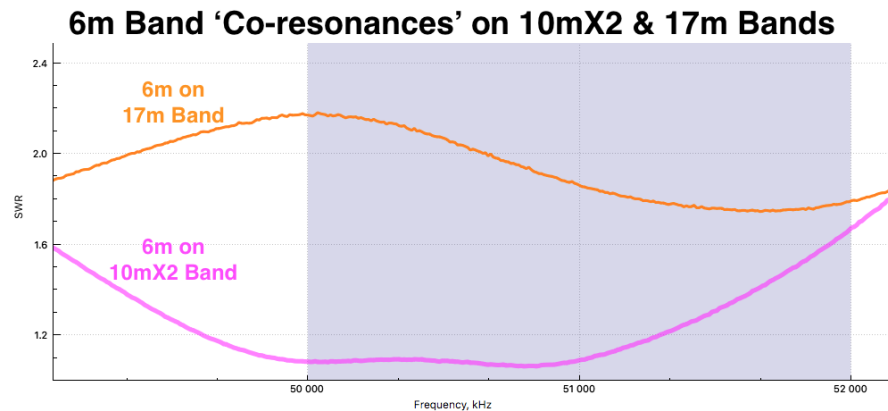
You can see this in the graph above, showing the shift rightward ('ADJust' shift) from the 17m band (its original tuning point) by +150 kHz to the green curve. This chart also shows the 17m SWR curve when the antenna is nearly touching the ground (yellow curve). Operating the Hen-Delta at different heights above ground alters the take-off angle between DX use (high above ground) and local or regional use (lower to ground), but alters the tuning slightly – about 100kHz in this case – an SWR increase of 1.2 above the green curve's minima. For most bands this shift with decreasing height can be ignored and the Effective Radiating Power (ERP) will still be >98%, but differing heights above ground might require the tuner's C & L optimum settings to be tweaked very slightly. Auto-tuners might not even notice the difference.

The above SWR shift 'near ground' was incidentally noted while repairing and testing the band selection relays' 3A 1000V diode (p95, lower right terminal block). Evidently the diode's 1000V rating is insufficient given the multiple fly-back spikes from the coax and shorting relays when switching bands. I added a 0.01 uF disk capacitor (the size of a quarter) in parallel with the diode to absorb a portion of the spike. If the diode fails again I will try protecting it with a MOV, two zener diodes, or even an NE2 lamp as a 70V gas discharge tube (GDT).

## 6mX3 ‘Co-resonances’ on 10mX2 and 17m bands:

April 2025: I am going to coin the term ‘co-resonance’ here to mean a single wavelength band approximately coincident with a secondary multi-wavelength band. For example, the 20m band is co-resonant with the 10m band, and the VHF band is co-resonant with the UHF band. I don’t know if this is a pre-existing term – I wouldn’t be surprised – but a simple internet search didn’t find it in use.

loop size needs to be reduced when caging is first introduced, relative to an uncaged single wire.



The above chart is obsolete but still illustrative. See p119.

The mechanical load reduction efforts above resulted in the need for minor re-tuning, and *by chance* the 6mX3 band showed a marked improvement on 10mX2 (at right). On the other hand, 6mX3 on 17m – when compared to the earlier SWR chart on page 102 – became slightly worse, but still usable. If the 6m band were of special interest it could be given its own tuning sliders, which would ‘lock-in’ an SWR curve similar to the lower curve below – it certainly couldn’t get much better!

It does seem that *multiple wavelength bands* like 10mX2, 12mX2, or 6mX3 on Hen-Deltas (and likely on all loop antennas) have broader bandwidths than single wavelength bands like 15m or 17m. Furthermore, where single wavelength band *slider pairs* on the tuning stub are typically separated by 5”-10”, multiple wavelength band *slider pairs* are typically about twice that distance apart.

I have also noticed that the higher the frequency of the band, the shorter (smaller overall loop length) its tuning slider positions are relative to simple arithmetic predictions. I suspect that there are capacitive effects as a consequence of caging which impact higher frequency slider positions more than lower frequency slider positions. This may also explain why the overall antenna

## 6-Band Antenna Parking:

With the 6-band Hen-Delta now at an awkward 25 lbs there was a need to develop a mechanism or procedure to allow one person to easily lower and park the antenna – perhaps very quickly if a storm arrived unexpectedly. Nothing so complex as ‘auto-furling’ a sail or pressing an ‘auto-park’ switch (although that is a fun idea!), just some means to reduce the workload from two persons to one. Here is my solution, admittedly site-specific. If you find yourself in a similar predicament and don’t have a deck handy, a nearby tree or some other structure might be placed into service...

I built a 4:1 pulley system from old pulleys and a ~45 lb weight (3 old brake rotors – thank you David AE0IZ!) with 10-feet of vertical travel under my deck. The procedure is illustrated at far right:



A) On the ground, I walk the free end of the 40-foot long ‘retraction’ rope over to the *already lowered* antenna (hanging a few feet above ground) lifting the 45 lb weight to its full height as I do so.

B) The retraction rope is attached to the *bottom* ‘U’ of the tuning stub, and the ~11 lb rope tension pulls the tuning stub towards and under the deck as the Halyard line is let out from up on the deck.

C) Back on the ground, the next step is to manually walk the tuning stub the final 6-8 feet under the deck. The retraction weight will hold it there.

D) Now a second rope from pulley P2 (magenta) is attached to the *top* of the tuning stub so that it won’t drop to the ground later. At this point in time the tuning stub, lower caged ‘downwires,’ and central rope’s tension adjustment nylon bolt are more or less horizontal (kind of an ‘arc’, really) and a few-to-several feet above ground, thus easily accessible if any work is needed.

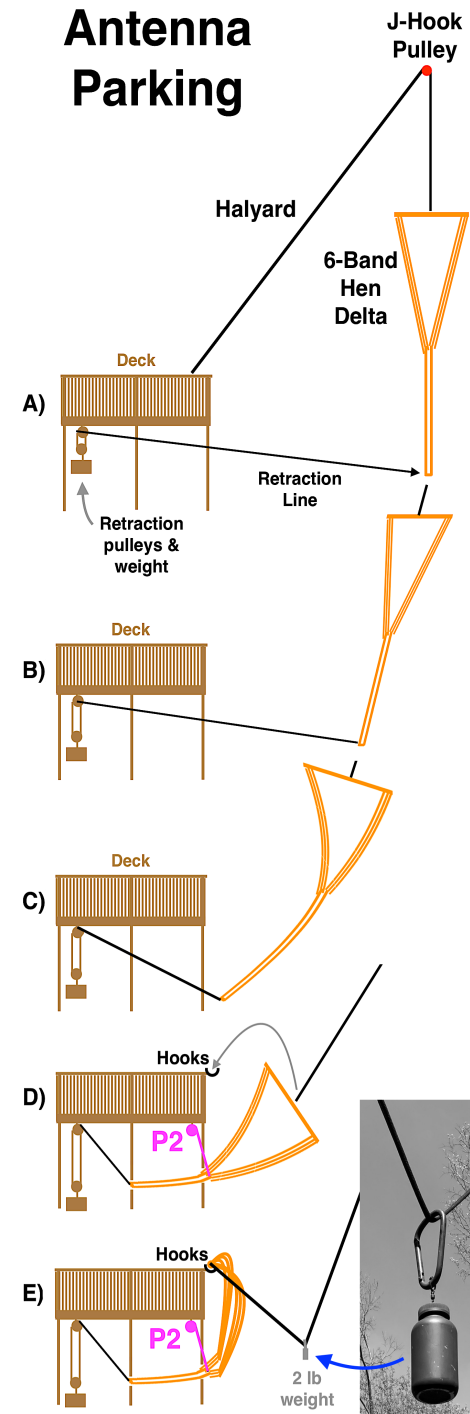
E) Back up on the deck, the antenna’s top element is pulled in and placed on ‘parking hooks’ on the deck’s railing. The halyard line itself is subject to tree limbs swaying in storm gusts, so a small 2 lb weight (a large vitamin bottle half full of gravel) with a large D-ring is clipped over the halyard line and slides down it to form a ‘V’ shape. The halyard line is then manually let out about 15-20 feet to provide a massive amount of slack in the line so that the antenna is never affected by tree limb movements in storms. This slack also prevents the

J-hook and the tree limb itself from transient gust loads due to the halyard line becoming taut. The 2 lb weight also dampens and constrains the halyard line’s movements so that gusts can’t blow it into other nearby tree limbs, as it would likely (and has) then become entangled there – a potentially distressing complication.

E) Finally, the *top* end of the tuning stub is fully raised (not shown) via pulley P2 (magenta) and the retraction line is detached from the bottom end so that the tuning stub can hang vertically, allowing the rain covers to be effective in shielding the relays and coax connections. A simple hook mechanism immobilizes the bottom of the tuning stub to a deck post. Being under the deck, it is also safe from hail.

The entire process can be completed by one person in just a few minutes and is easier to do than to explain! Deploying the antenna just reverses the sequence.

## Antenna Parking



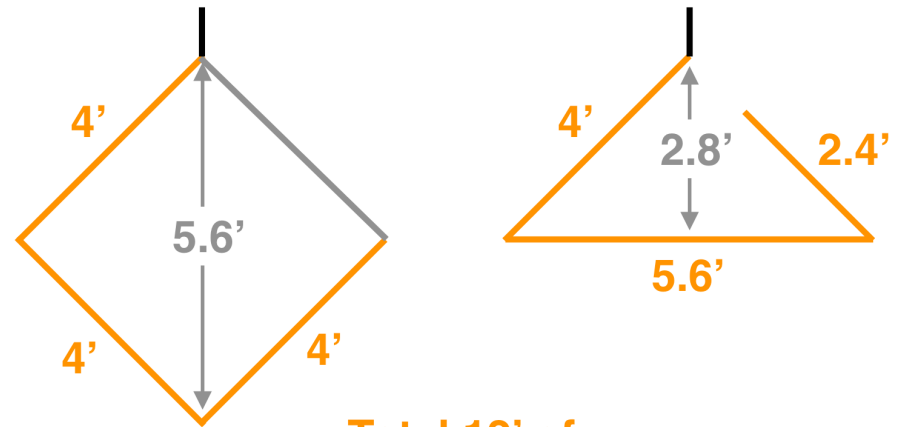
## 6-Band Tuning Stub Height Reduction:

If a 12' tall tuning stub is deemed too unwieldy, you might recall the brief investigation of inverted tuning stubs on p27. I suspect that *that* technique would be successful, but if one prefers to avoid the complexities and uncertainties of having the tuning stub within the interior space of the 'sail' area (that portion of the antenna above the tuning stub), there is always the possibility of 'folding' the tuning stub into vertically space-saving geometries, such as shown at right. Care would need to be taken to ensure that the (possibly rounded) corners of the new geometries didn't fall near likely slider positions. It's even possible that an RF-friendly circular or elliptical geometry might be achieved, if one only knew how to form 1/2" copper pipe with a precise radius at reasonable cost? The resulting diameter would be about 3'-4', allowing a little space for a gap near the top. Power for the relays might come from the geometrical center point.

Another interesting thought would be a folded tuning stub in the *horizontal plane* as shown at right (a square shape could be envisioned, too). Care would need to be taken to ensure that the top copper pipe and bottom copper pipes were the **same path length** from the cage junctions they attach to, although the copper pipe itself need not be elaborately formed – cage junction -to- pipe interconnecting wire routing geometries could equalize the path lengths prior to being attached to the tuning stub pipe. The presence of multiple tuning sliders (or dummy sliders) would maintain the separation distance between the top and bottom copper pipes, and short lengths of rope from the cage junction points (just below the two-hole lugs) to the top tuning stub pipe would support both of them.

No doubt these untested geometries would effect tuning to some degree, but I suspect any such effect would at least be *stable* and consistent.

## Plausible Tuning Stub Geometries To Reduce Overall Antenna Height



Total 12' of  
1/2" Copper Pipe



Stacking & Arraying Hen-Delta Antennas?

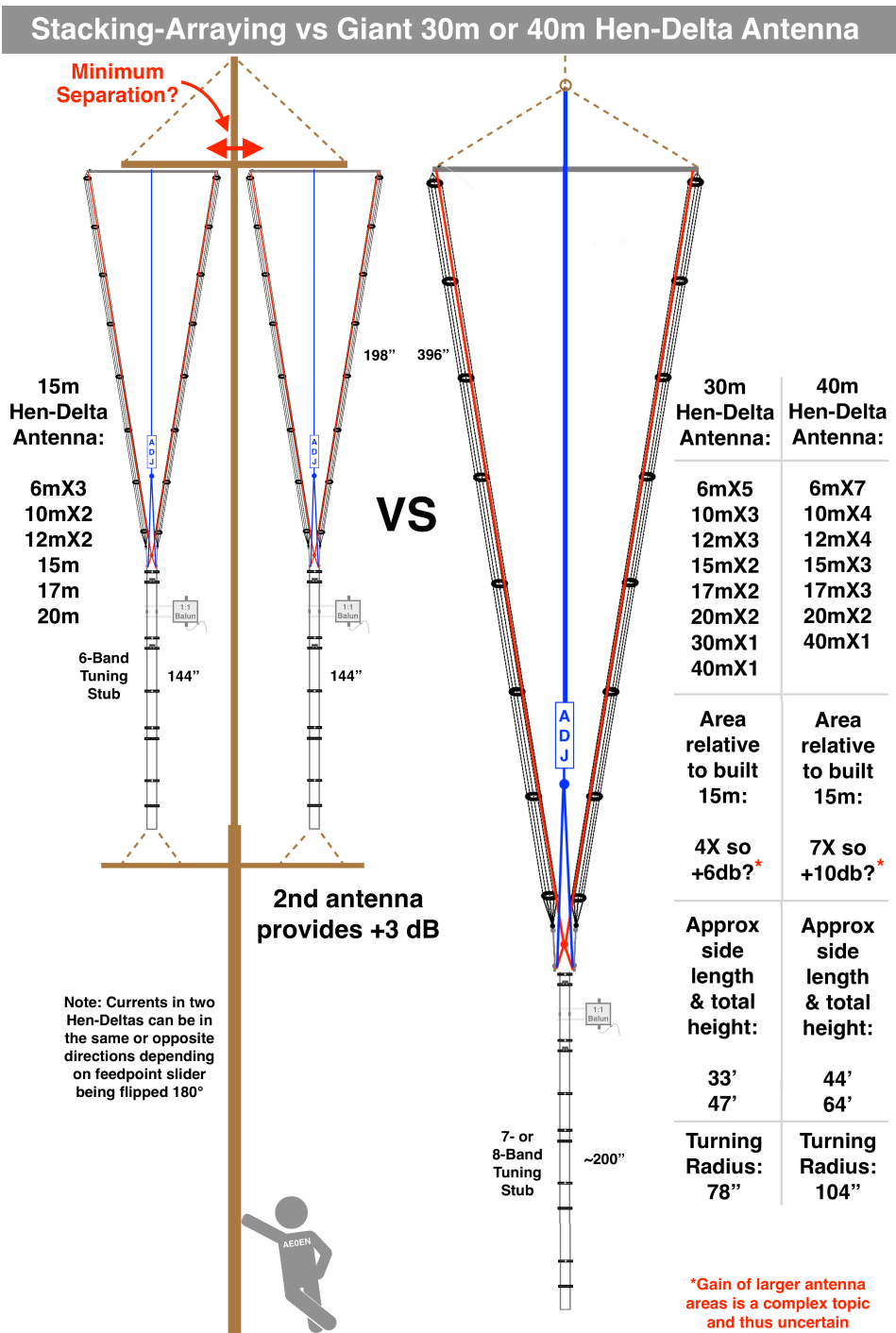
I have never tried stacking or arraying antennas so this is speculative, but I have seen photos of huge towers carrying a heavy load of yagi antennas and rotators to achieve this. The cost is astronomical, of course. Since the Hen-Delta is a such a low cost design – excluding the masts and foundations – it is fun to consider ‘Hen-Delta farms’! Each doubling of the antenna count *ideally* adds 3 dB of gain, so two such masts (4 Hen-Delta’s) adds 6 dB and four such masts (8 Hen-Delta’s) adds 9 dB. There may be some economies of scale with such numbers. The lower, ‘thick half’ of the mast could be carbon fiber or metal, while the more slender upper half would be non-conducting, like ABS pipe (comes in nesting 20-foot lengths) or fiberglass. There might be guy lines available as storm tie downs which in normal use would just hang straight down and be tied off near the base. Most arrayed antennas have a minimum separation distance of 5/8ths wavelength. I would prefer the relative simplicity of a single larger antenna (far right) if it performs in proportion to its area...

Giant, Multi-wavelength Hen-Deltas?

On the far right of page 101 you will see something interesting – the 6-band antenna has a *much stronger* two-wavelength signal on 10m than the single wavelength 10m antenna. While not definitive because of the different heights above ground (55’ vs 40’) and therefore seeing slightly different take-off angles, it is *suggestive*. As a general (or absolute?) rule, antennas with larger areas receive *proportionately* stronger signals. This begs the question: **Would we be better off building a large 2-, 3-, or 4-wavelength Hen-Delta than stacking or arraying them?** This is a question of cost vs weight vs performance, because tuning stubs are heavy, requiring materials and labor in approximate proportion to their number, although there may be some economies of scale. Stipulating the existence of the necessary support structure or a handy Sequoia tree, might it not be far easier to build, for example, a single 3-wavelength, 10m Hen-Delta than to stack or array several smaller ones? Hypothetical 30m & 40m Hen-Deltas are shown at right with their necessarily long tuning stubs. A single large antenna would be easier to build, lighter, less costly, and perform better than an array of two small antennas. See p115 for some discussion about *radiation resistance*.

This also brings to mind the question of lobes and nulls for such a multi-wavelength antenna. With a *horizontal loop* the lobes and nulls fall as they may, and their benefit is ‘hit or miss’ depending on where the far station is relative to them. But the Hen-Delta is steerable so the lobe’s gain can be fully utilized.

These would be fine questions to computer model (simulate) someday.



## The Evolution of the Caged Hen-Delta Antenna:

Here is nice timeline overview of the evolution of the Caged Hen-Delta antenna.

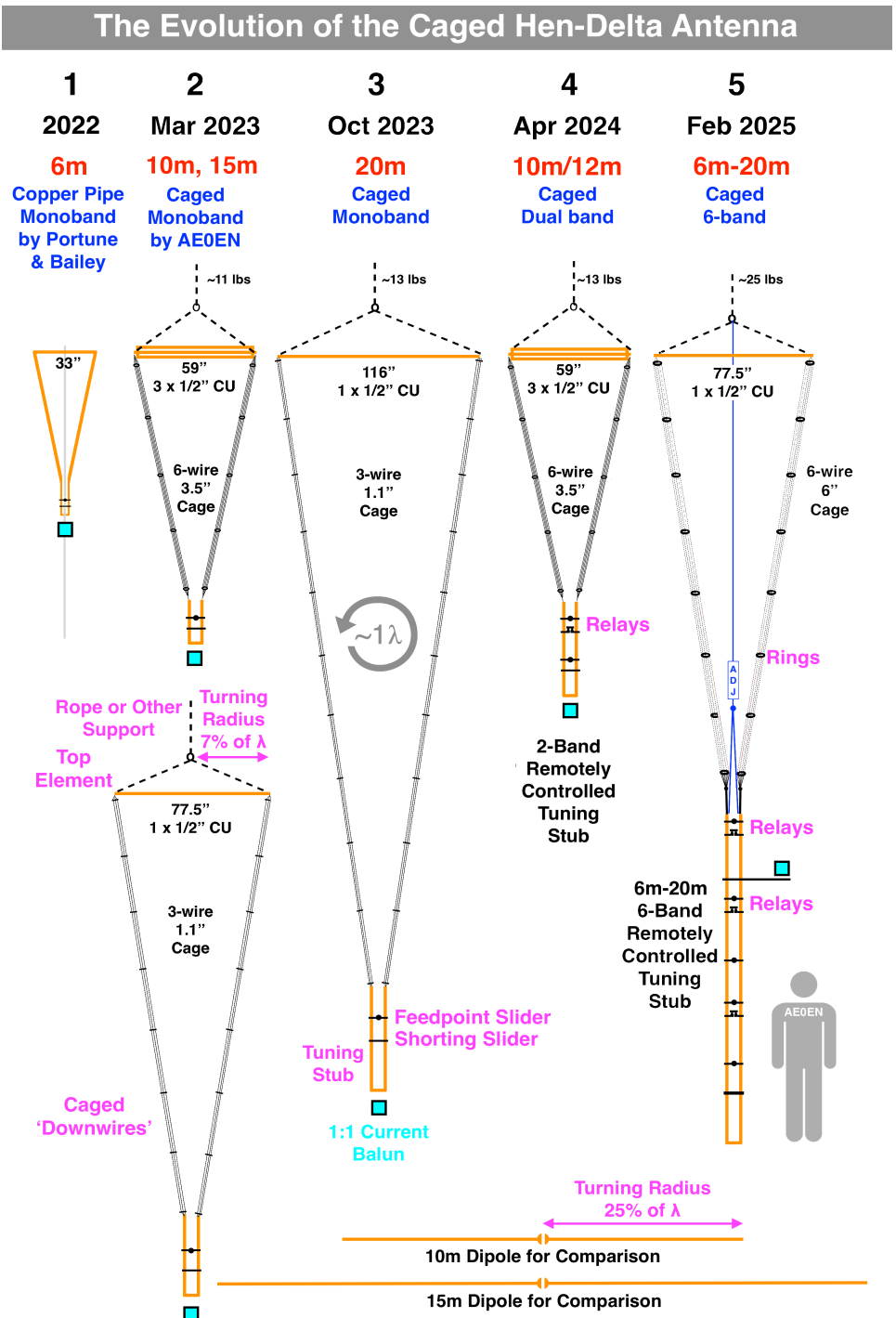
### Building Your First Hen-Delta:

For one person, a 6-band, 6m-20m Hen-Delta is an ambitious project. I recommend those new to the Hen-Delta begin with a one- or two-band manually switched version for simplicity and low cost, in order to gain experience with supporting structures (trees, masts, or preexisting towers), the tuning stub, caging, rotators, and so forth. You might choose an initial size that lends itself to future tuning stub expansion – you can always replace a small tuning stub with a longer one later – I have done so several times. 36", 40", or 60" tuning stub lengths are good starting points, depending on the band in question. If you wish you can always cut it shorter later, but if you do, always leave 16"-18" below the last shorting slider for future tuning adjustments – the shorting slider loses effectiveness as it approaches the very bottom of the stub.

I would suggest **one** ½" copper pipe for the top element and tuning stub, a 250-foot reel of 12-gauge brown stranded wire from the hardware store, ABS rings for caging, two-hole lugs for the four major connection points, and 8-gauge solid copper wire for the leads. PVC rings *might* work, but could get brittle in cold weather – I've never tried them. Use only stainless steel bolts, and quality ¼" or larger Dacron rope. When the antenna is completed apply some ultra-flat camouflage spray paint if stealth is a concern – and try to leave a few inches of copper near the sliders unpainted in case they have to be adjusted later (although the copper pipe can always be cleaned with a foam sanding block). Other construction details are given throughout this paper.

I did a quick tally of costs as of April 2025. A tree-supported, mono-band or manually switched multi-band antenna (thus no \$125 CX600M relays) will cost about **\$120** worth of copper pipe, wire, ABS pipe for rings, 2-hole lugs, and hardware. The required 1:1 current balun (mine is a 3.5KW Balun Designs model 1115) will add **\$80**, unless you can make your own. **Thus the total for an operational antenna is about \$200.**

But you still need to get the antenna into the air and steer it. A 57mm stainless steel sailing block (pulley) costs **\$35** and the ¼" Dacron halyard line and 1/8" steering cords another **\$50**. 100-feet of RG-8X coax with PL-259 connectors is about **\$80**. A weatherproof 12-volt, linear actuator (high speed, low force) for



the homemade rotator costs under **\$60** (note that you *can* manually steer the antenna to test it). If desired, an ‘RV backup camera & 7” HD monitor’ to observe the antenna’s exact orientation is **\$80**. **These ancillary items total about \$300**. Compare that to the cost of multi-band yagi antennas on towers: *thousands of dollars!* The entire project will take you a few weekends, after which you will be “traveling the world at the speed of light!”

There is no such thing as a ‘perfect’ antenna, but the Caged Hen-Delta offers an **appealing** blend of DX qualities and low cost! With these antennas  $\geq 1$  wavelength above ground I have worked 96 countries *beyond* the first 80 countries previously worked with horizontal loops. Total 176 countries *SSB-only* as of this writing. For example:

- >5000 miles: Too many to list.
- >8000 miles: Eastern Australia, New Zealand, South Africa, Tanzania, Namibia, India, Thailand, Cambodia, Vietnam, Indonesia, Philippines, Norfolk Island.
- >9000 miles: Central Australia, Tasmania, Madagascar, Seychelles Islands, Malaysia, Indonesia.
- >10,000 miles: Western Australia, Reunion Island.

My personal distance record from here in St. Louis, Missouri USA is to Perth, Australia – 10,885 miles or 17,517 km. Propagation was good but not ‘magical’, with QSB and some noise. We both logged signal strengths of ‘44’... but ten minutes later it would have been ‘55’.

Anecdotal notes: On 2025-0524 with the 6-band caged Hen-Delta and 700W, I worked Jerusalem on *20m* (6473 miles) and the Seychelles Islands on *17m* (9268 miles).

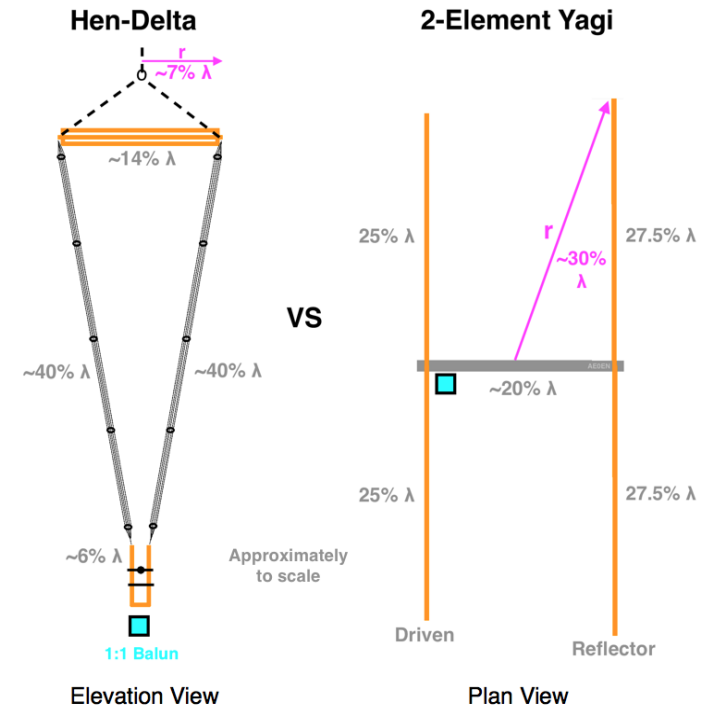
## Hen-Delta vs 2-Element Yagi Comparison:

Here is a simple comparison of a Hen-Delta to a two-element Yagi.

Because the Hen-Delta is a ‘skeleton slot’ class antenna, it is said to have a *slightly* lower take-off angle than other antennas. I have no way to test this, but its performance is very good by the simple standard of working far away DX. In any event, the higher above ground the better, and the Hen-Delta is lightweight and small, which helps in getting it higher. Actually, height – at least up to 2.5 wavelengths – is more important than gain (see Chapter 24).

During a recent QSO with a Colorado amateur I learned that typical 10m, 15m, and 20m yagis weigh roughly 40lbs, 70lbs, and 120lbs respectively, excluding

## Hen-Delta Features Comparison



|                   |  |                 |
|-------------------|--|-----------------|
| Azimuth gain:     | ~3-4 dBd   | ~3 dBd          |
| Bandwidth:        | Very Wide  | Narrow          |
| Turning Radius λ: | 7%   | 30%             |
| Directionality:   | Bi-directional                                   | Unidirectional  |
| Tuning via:       | Sliders (easy)                                   | Element Length  |
| Relative Cost:    | Low cost   | High cost       |
| Weight:           | Low weight                                       | Moderate weight |
| Storm Survival:   | Varies depending on support, but easily 'parked' | Good-excellent  |

the heavy rotator. Contrast that to the 6-band caged Hen-Delta at 25lbs with a likely ground-mounted rotator. Of course, a tree-supported caged Hen-Delta should be ‘parked’ before storms or high winds, or when not in use for an extended period, whereas yagis are tough enough to ‘weather the storms’. However, this also means the Hen-Delta is more easily accessible for tuning, repair, or modification.

## How do two-wavelengths fit on the caged Hen-Delta antenna and 6-band tuning stub?

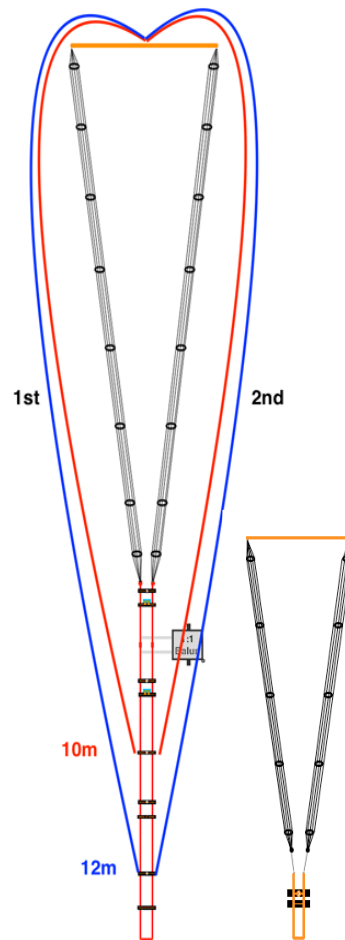
The illustration at right shows how the very long tuning stub supports multi-wavelengths. The 10mX2 (10m ‘times 2’ wavelengths) vs the smaller 10mX1 antenna (see inset for relative size) signal strength comparison is shown at right on p101. The 10mX2 band is much stronger, most likely due to the **greater antenna area** (about double) of 10mX2 vs the smaller, original 10mX1. However, during the comparison on p101 the two antennas were at different heights above ground (55’ & 40’ respectively), and this may have been a contributing factor as well.

## Why hasn’t the 6-band Caged Hen-Delta been *simulated*?

Everything in this PDF is *empirical* – build it and test it. This has always been the best method to test and understand an antenna when practical. Simulations can be useful tools but they also have limitations and fallacies which are *not* always obvious and take a great deal of experience to be wary of. I have none. I have heard and read other amateurs discuss this topic and some of the free ‘EZ’ software is quite limited in scope, which won’t prevent it from producing ‘results’ – just not accurate results. Perhaps even *misleading* results. Skeleton-slot antennas are a very unusual class of antenna. Portune and Bailey’s modeling (see link on title page) utilized a very advanced and expensive simulation engine. By the way, check out MMANA-GAL simulation software. I have been told it is much easier to use than EZNEC and considerably more accurate. I haven’t used either myself.

For this reason I long ago made the decision to leave that aspect of exploration to those with the necessary experience and professional-class software. If you have both, there are many aspects of the Hen-Delta that can be explored...

Two-Wavelengths for  
10mX2 (red) and 12mX2 (blue)



- Director/Reflector optimization per band?
- Radiation pattern vs height above ground in wavelengths?
- Gain of scaled-up, multi-wavelength Hen-Deltas such as on p111?
- Is polarization affected by odd/even wavelength count?
- Does odd vs even wavelength count affect the radiation pattern?
- How does wavelength count affect the radiation pattern’s lobes and nulls?
- Is there a better optimization of the ‘skeleton slot’ effect geometry, such as by introducing a spreader bar somewhere in the lower portion of the skinny delta?

There is much work remaining to fully understand this delightful, efficient antenna! Please contact me through my QRZ page email link or mailing address if you would like to do some simulations.

## Do Trees Attenuate HF:

Practically speaking the answer is ‘no’. A few years ago I read about a U.S. Army study during the 1930-1950 period which concluded that VHF, UHF, and higher frequencies *were* attenuated by trees and jungles, but that HF was not significantly effected. This is good news for those of us who can *only* get consistently good DX performance at heights above ground that a tall tree can provide!

## Is the Caged Hen-Delta the ‘Best’ Antenna for You?

Maybe... or maybe not. It depends on your goals and your site. In my short amateur radio career I have erected several omnidirectional horizontal loops – and they are a fine antenna to begin with. I have had a 40m horizontal loop, an erectable and tall 60m (used on 6m-40m, see p80), an 80m loop about 40-feet above ground through trees. I have used low 80m loops at the local club during field days. I have used the omnidirectional W3EDP vertical. The caged Hen-Delta blows them all away, but of course *it* is bidirectional, and 1–1.6 wavelengths above ground – **because they can be** – and height is more important than gain – per page 74.

The phrase ‘because they can be’ is worthy of attention. First they are light-weight, as modest-gain antennas go. That alone makes getting them to a better height easier. It has a low ‘wingspan’ profile so that lateral support lines or braces aren’t needed, and it has a very stable geometry. Even if you pick a higher gain antenna – and there are many – could it be raised 55-feet up into a

tree and be rotated within a tall vertical cylinder (cone, really) of space just 6.5-feet in diameter? I'll bet not! This is all the *high* antenna space that *I* have to work with. A higher gain antenna would be wonderful, but if it can't be placed at a useful height above ground, or rotated once it is there, it is of no practical use.

So if you need a *quiet* antenna with a tiny turning radius of 7% of a wavelength (~5% for the 20m band on my 6-band, 6m-20m antenna!) in order to get it high enough for good DX, the caged Hen-Delta may be for you. Or if *low cost* and relative simplicity – for the gain provided – appeals to you, it may be a good choice. If you are not allowed to have permanent masts or towers, it might be your *only* choice for an antenna with some gain.

One final point: To me, the 'best' antenna is the one that **consistently** reaches out further than others which might be employed *at a given site*. All the complex technical measurements and complicated calculations are, in the end, subordinate to this simple functional goal. On April 28, 2025 I worked Perth, Australia, long after sunset here, on 10mX2 with my 6-bander, sending 300W in his direction. Perth is 10,885 miles away – my present distance record. The caged Hen-Delta is my best antenna... to date. I say 'to date' because I have been toying with the idea of building a 30m Hen-Delta (see p111) with **4 times the area** of the original caged 10mX1 Hen-Delta for the purpose of comparing its signal strength against the present 6-bander and the original 10mX1.

I don't use my horizontal loops anymore and have decommissioned all but one (needed just for 40m) because they have simply reached the limits of their DX capabilities. Having worked my first 80 countries (the 'easiest' 80) with a loop, I was reduced to adding only about one new DXCC country per month. But when I switched to the caged Hen-Deltas, that jumped to 1-2 new countries *per week* – I was working a whole new DX radius roughly 2500 miles further away! The next 96 countries were with the caged Hen-Delta, total to date 176 out of the possible 340. Most of the remaining countries are very far, or so sparsely populated (if populated at all) that they require a DXpedition. Having now worked the 'easiest' 176 countries, new ones are gradually getting harder to find again... but I will work them as opportunity permits.

## Further Study of Slot Antennas:

I found these two articles especially useful...

Do watch the video at the end of the article:

<https://www.antenna-theory.com/antennas/aperture/slot.php>

"...There is no radiation at the slot ends..."

<https://www.qsl.net/n3zpc/The%20Skeleton%20Slot%20Antenna%20Revisited.PDF>

## Finding DX:

There are several important web sites to help you find active DX and DXpedition call signs, frequencies, locations, and great circle compass headings:

### *Real Time World Map:*

This is a really valuable resource showing a world (or regional) map of active DX communications. *Hovering* over a call sign reveals the frequency, time of last report. Clicking near it shows the distance (short and long path) and the compass heading for your antenna. It shows the location of the sun and you can have it show the gray line (terminator line). Humorously, on occasion someone will typo in a 'spot' with the wrong call sign or location, creating a tag in the middle of nowhere of eyebrow-raising interest to many... but they are eventually corrected and disappear. It is always necessary to listen carefully and confirm that the call sign is actually what and where the map says it is.

<https://www.dxmaps.com/spots/mapg.php>

### *Announced & Active DXpeditions:*

<https://ng3k.com/Misc/adxo.html>

### *DXpedition News:*

<https://dxnews.com/dxpeditions/>

### *Contest Calendar:*

There is a useful contest calendar providing contest date, time span, bands, modes, and information exchange specifications per contest at:

<https://contestcalendar.com/weeklycont.php>

### *Logging:*

And of course, you will want to log your QSOs. In the USA **QRZ.com** is often the online logbook of choice and is mostly free. In the U.S. and elsewhere 'Logbook of the World' (LoTW) is also commonly used. QRZ.com is a somewhat casual contact entry site, while LoTW is very rigorous.

## A Symbolic Illustration of Antenna Power Radiated, Lost, & Reflected:

May 11, 2025: Lengthy discussions with some very bright and experienced amateurs – *Many thanks to Andy SVIDKD & the Radio Amateur Association of Western Greece SZ1A* – helped me to slowly evolve my own understanding and create the *hopefully clarifying* illustration at right. **You may zoom in on this page to see the many fine details more clearly.**

There are three ways that antennas interact with RF energy. First and best they radiate it! Second, they get warm. Third, through mismatched reactance they reflect the energy back toward the source.

**1) Radiation resistance** is an unfortunately confusing term. Let's examine what it refers to:

Consider an electron in the upper  $R_r$  portion of the illustration as it is accelerated in a wire. It has a velocity of  $v_1$ . Some time later the electron emits an RF photon and the energy for that photon,  $hf$ , comes from the reduction in the velocity of the electron, now a smaller  $v_2$ . (I am curious if  $hf$  is 1% or 100% of  $V_1$ , but it doesn't matter for this discussion.)

This reduction in velocity (momentum) can be thought of as a 'braking' or 'recoil' force acting in **opposition** to the electric field in the antenna accelerating the electrons. So it *appears 'like'* a resistance. But resistance is a passive ohmic force, and electron velocity reduction is an active consequence of RF photon emission – a **good** quality in an antenna. It is called the *Abraham-Lorentz force* (see Wikipedia, 'radiation reaction'). I would suggest that a better name might be something like: 'photon emission recoil' or 'photon emission braking' as these at least directly describes the *causal mechanism*.

As you would expect, the more photons that are emitted the better, so the more 'radiation resistance' (think: *RF photon emission*) an antenna has, the better! But as David AE0IZ pointed out to me, this is a metric of antenna efficiency – if you put 100W into an antenna you will at most get 100W worth of RF photons out of it.

**2) Ohmic Resistance**, also called DC resistance, is a well known aspect of antenna design. The lower the better since the less energy that is wasted as heat the more that is available for Rf radiation. In classical physics heat is produced when electrons traveling through a conductor (see 'a' or 'c') bump into things (see 'b' or 'd') and slow down, thus emitting an infrared (IR) photon. This pho-

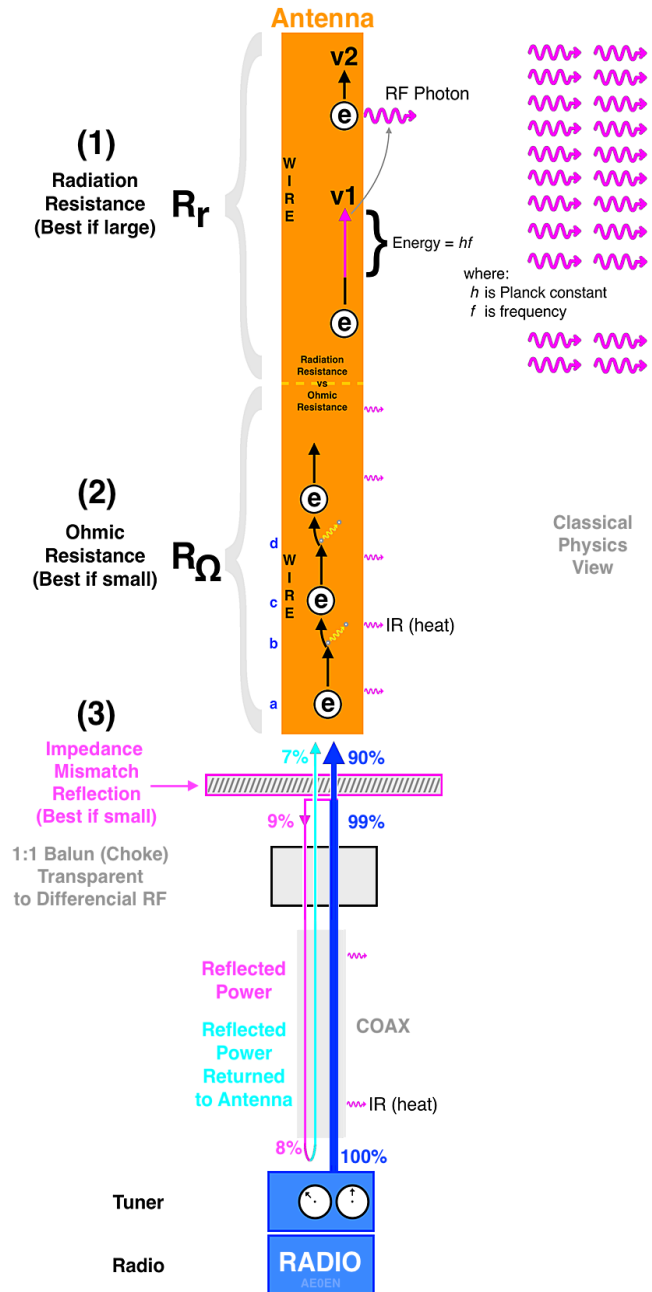
ton rarely leaves the conductor's interior and is absorbed by the surrounding atoms, warming the material, which then in turn radiates IR photons.

Ironically, these IR photons, being of a frequency just a little lower than visible light, each have far more energy ( $hf$ , see *illustration*)) than the much lower frequency RF photons – but there are vastly more RF photons than IR photons!

**3) Impedance Mismatch Reflection** occurs when the antenna possesses either inductive (+j) reactance or capacitive (-j) reactance. These are clearly seen in Smith charts when the antenna trace is above (+j) or below (-j) the horizontal centerline (zero j, or purely resistive). Either results in RF energy being **reflected** back towards the source, and increases the SWR.

How far this reflected energy goes depends

## Symbolic Illustration of Antenna Power Radiated, Lost, & Reflected



primarily on whether you have a remote auto-tuner near the feedpoint of the antenna. If you do, then the reflected energy is immediately re-reflected back to the antenna with very little energy lost.

If, like me, you have a tuner in your shack, then the reflected energy will return all the way to the tuner before being re-reflected back to the antenna. This means the reflected energy will make two additional one-way trips through your transmission line (coax typically) and be subject to those losses that it imposes.

There is a common misconception that a choke or 1:1 balun will return reflected energy to the antenna. These devices are transparent to differential energy and only block common mode signals.

Simplistically, to see how energy is lost in coax examine the lower portion of the previous illustration. **100% (100W) of the RF energy leaves the tuner** and travels through the coax, losing a hypothetical 1% (1W) along the way and heating the coax slightly. 99% (99 watts) arrives at the antenna, but due to an **impedance mismatch**, (let's say) 1/11th of 99% or 9% (9 watts), **is reflected back toward the source**. In that case 90% (90 watts) enters the antenna system and is radiated, mostly as RF but also a little as heat.

The 9% (9 watts) that is reflected back toward the tuner traverses the coax back to the tuner and is **then sent back toward the antenna**, losing (say) 1% (1 watt) on each leg of that trip, for 2% (2 watts) total. Approximately 7% (7 watts) enters the antenna for a total of 97% (97 watts). Further tertiary reflections will add a small factor that we can ignore here.

Thus within the antenna 97% (97 watts) will be radiated mostly as RF photons, but also a little as heat – determined by the *ratio of the radiation resistance and the ohmic resistance* of the antenna.

**Sidebar: I was interested to learn that the returning reflected energy does not impinge upon the antenna as discrete or distinct arrival events, 1-2-3, separated by the round trip time in the coax, but is actually fully integrated into the primary RF energy transmission.**

In our caged Hen-Delta, each side consists of six 12-gauge wires with an equivalent ohmic resistance of one 4-gauge wire. The top and the tuning stub are ½" copper pipe. The net result is that the caged Hen-Delta has a loop resistance of just 16 milli-ohms (measured with a 5½ digit, 4-wire resistance bench meter with the antenna disconnected from the balun and the loop opened at a pigtail.),

therefore the vast majority of energy is radiated as RF – hardly surprising but it's nice to have real numbers.

Getting back to the large antenna of p111, when an antenna's size is doubled its area increases 4 times, but its 'radiation resistance' (photon emission) increases as *the square of the area*, so 16 times! But wait – this only applies to antennas that are electrically small compared to the wavelength in use. The hypothetical 'supersized' 30m Hen-Delta in question is two-to-five wavelengths of 6m-20m (ignoring the 30m band itself)...

...But is it **really multiple** wavelengths? Off-stage discussions with other 'Elmers' have suggested that perhaps (?) most of the radiation *may* (?) come from the *top portion* of the antenna, which is at a minimum 14% of a wavelength (the copper pipe itself) and perhaps as much as the upper half of the loop. This portion of the antenna might actually **be less than one wavelength**, in which case the 'square of the area' relationship would still apply, or nearly so. The suggestion was that the side 'downwire' cages *may* (?) be better thought of, more-or-less, as quasi-transmission line.

I am uncertain. I do know that it is the caging of the downwires that provides the broadband effect, and that effect does **not** diminish as you approach the tuning stub (see 'fractional caging' on p49). So if the downwires, top to bottom, were 'just only' quasi-transmission line, how could they contribute in equal percentages to the broadband effect? I suspect that a careful and exhaustive modeling of this *skeleton slot* antenna will be required to clarify and fully explore its nature and behavior.

Until a rigorous study is completed, we must good-naturedly endure the tangled web of amateur radio knowledge, half-knowledge, misunderstanding, and echoed opinions: each of us among 'the blind men who describe the elephant by touch', according to our own scattergram learning curve of experience and discernment, often applied with absolute confidence in scenarios of marginal relevance... because our knowledge base is, after all, *all* that we have to work with! To be fair, you could spend many lifetimes studying amateur radio and *still* not cover every nook and cranny – it is an infinite field of study within the greater infinity of physics.

So how does a super-sized 'multiple-wavelength' caged Hen-Delta behave with respect to 'radiation resistance' (photon emission) vs size, as a hoped-for metric of performance? I don't know yet – 'it's complicated.' I *may* have to build one!

## Smith Chart for Caged 6-band Hen-Delta:

May 12, 2025: I don't use Smith Charts very much but I thought I would include one for those of you who do.

Each band is fully plotted except 6m, shown separately on the following page.

These 5-bands were optimally tuned for the SSB regions of each band and these SSB plot segments are shown as a solid line between two large dots. The CW portion of each band is shown as a dashed line. Each band could, of course, have been optimally tuned for CW – but in practice the plots are easily good enough for both CW and SSB.

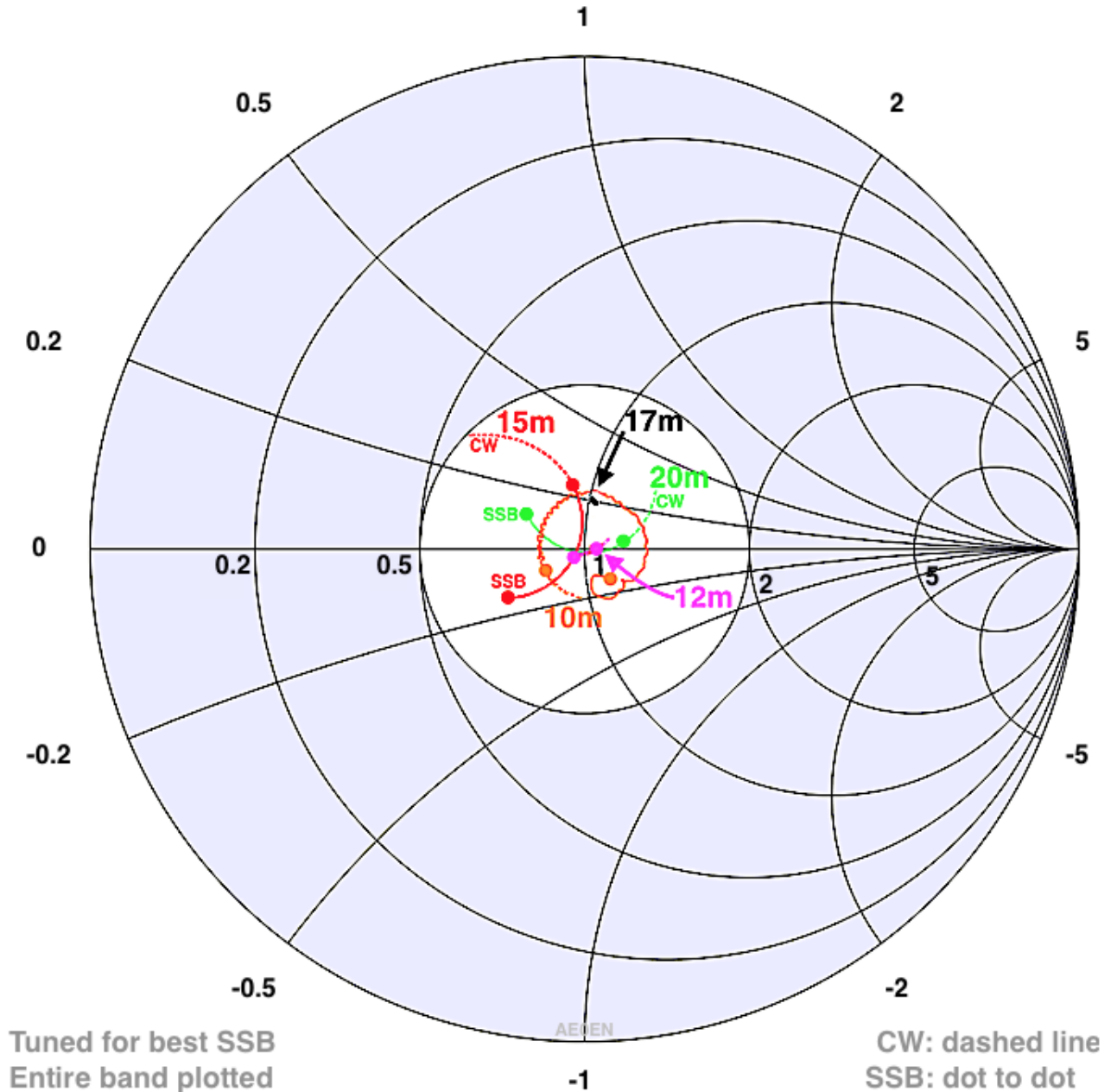
Note that as a consequence of some recent and modest re-tuning, the *entire* 10mX2 band is supported at a reasonable SWR. This wasn't deliberate it was just happenstance – I almost never use the upper half of the band.

17m is such a small band that its SWR curve is essentially flat, so here it is plotted as just a very short black 'dash' (see black arrow). 12mX2 is similarly short.

Ignoring the CW portions of all bands, the SSB plots stay within a fairly tight region near '1', and are thus very well behaved, efficient, and easily tuned by my Palstar tuner.

This plot was generated by RigExperts' AntScope 2.2 software (PC or Mac) from the same saved data that the SWR curves were based on.

## Smith Chart for Caged 6-band Hen-Delta (except 6m)

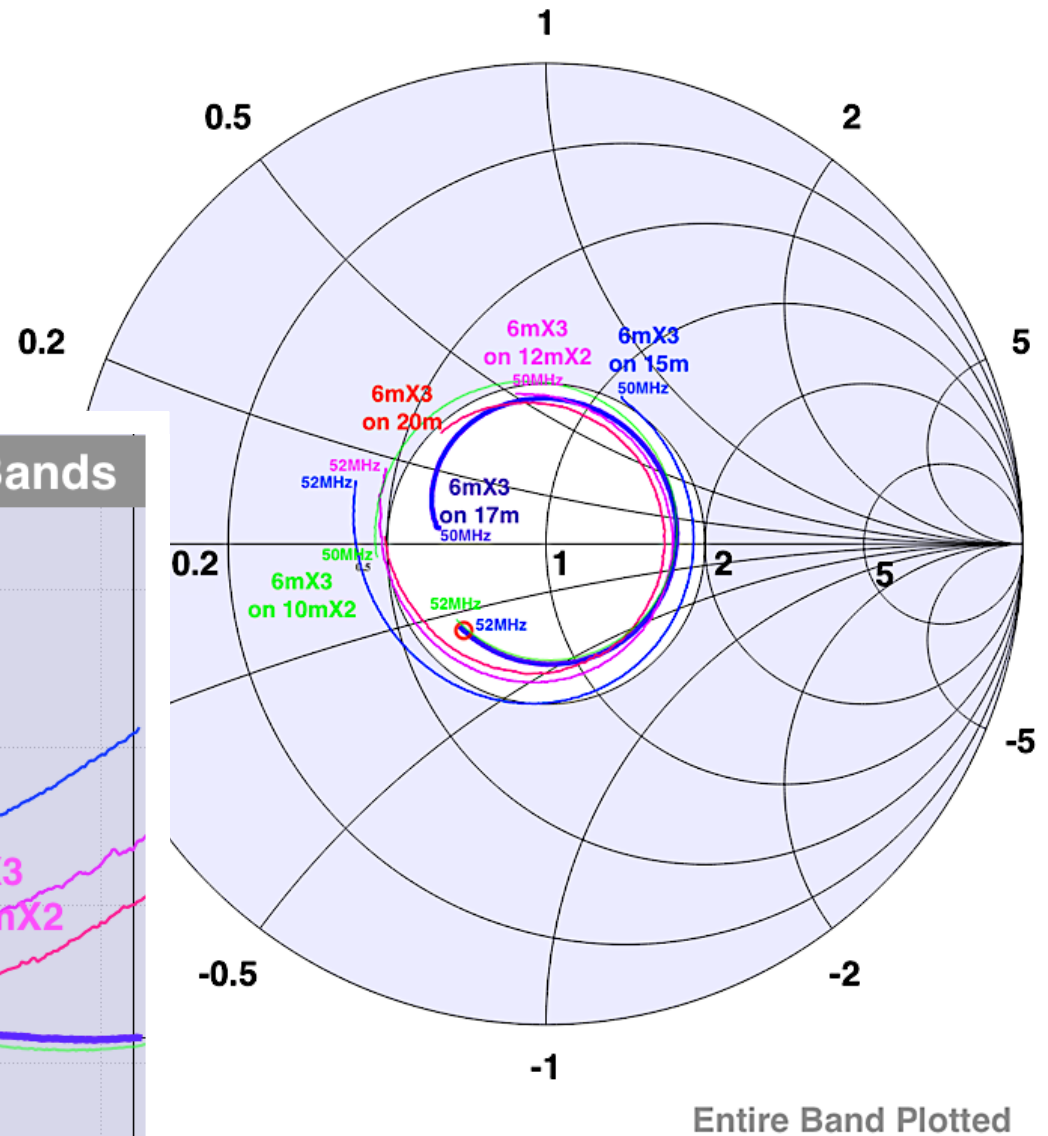


## Smith Chart for 6mX3 on Co-Resonant Bands:

As a 'free' co-resonant band 6mX3 falls as it may on several other bands, varying if and when these other bands are re-tuned. I almost never use 6m, but if it is important to you, you may certainly add a pair of dedicated tuning sliders ('taps') for it.

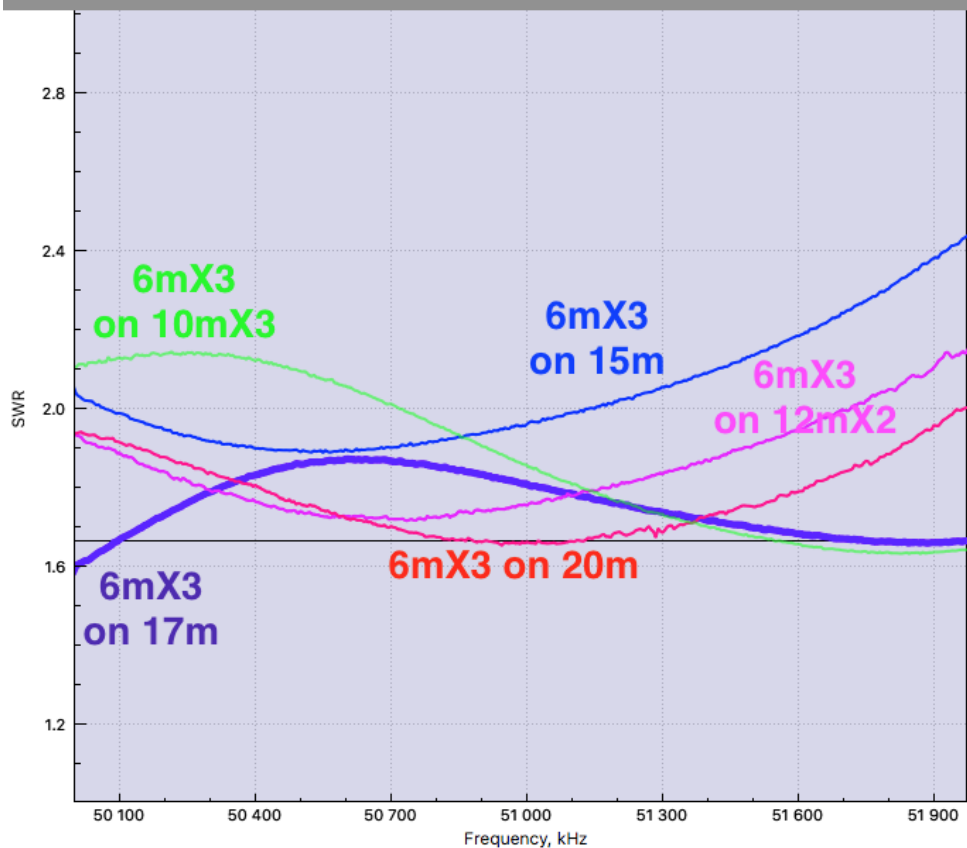
As shown below the best co-resonant band – especially for the lower portion of the band – is 17m, which is a permanent, always-available band – with an SWR ranging from 1.6 to 1.9 *for the entire 6m band*. This is in the ballpark of 95%-90% ERP (effective radiating power) and certainly adequate for occasional use. Note that coax losses at 50MHz frequencies can become significant and will reduce the ERP further.

## Smith Chart for Co-Resonant 6m on 10m-20m Bands



If you were interested in the center of the 6m band then 20m might be the better co-resonant band.

## SWR Charts for 6m Co-Resonant Bands



## Thoughts on building a portable ‘roll-up’ Hen-Delta – *The 6-Band / 6-Pound Hen-Delta Challenge:*

2025-0822: I have missed many marginal ‘33’ QSOs with amateurs operating remote portable stations using QRP-100W and simple omnidirectional wire antennas – which are certainly convenient, lightweight, and low cost for travel and battery operation. But given the suburban noise floor here I often wish DX-peditions using SSB could deploy a lightweight antenna with modest gain to increase their signal strength and DX range – in many cases that is all that it would take to increase signal strength to workable ‘44’ and ‘55’ levels. **Allow me to suggest such an antenna:** a Hen-Delta would be a fine choice if it could be made light and flexible enough to be ‘rolled up’ on a cardboard tube for transport. Note that 8”-12” tubes are available as concrete pier forms at hardware stores, and roll-up foam pads for sleeping bags might serve double duty.

I believe that a design along the lines shown at right could achieve this weight goal – although I have not yet built one. The heavy ½” copper pipe has been replaced with 12-to-14-gauge solid wire, and the tuning sliders (taps) simplified using one of two movable connection methods for tuning: copper ‘lay-in lugs’ or aluminum split bolts (both on Amazon). The split bolts are much lighter and could even be removed entirely if the final tuned positions are soldered (blue circles). The loose black nylon wire clamps keep the wires from getting wildly out of position, but allow vertical movement. To save weight no relays are used – the bands are changed manually in the field by moving the feedline to a given band’s feedpoint connector: be it SO-239, BNC, or SMA – the later being much lighter weight but limited to 100W or so (some SMA connectors are rated for 250W CW, but for portable operation 100W is really sufficient). The feedline carries a tethered shorting ‘bar’ (a ¼” copper slug). Only the selected band needs the feedline and shorting bar. (Detail: For Option-1 the shallow dados prevent the lugs from pivoting. The SO-239 or other connector style should be facing downward as shown on p98).

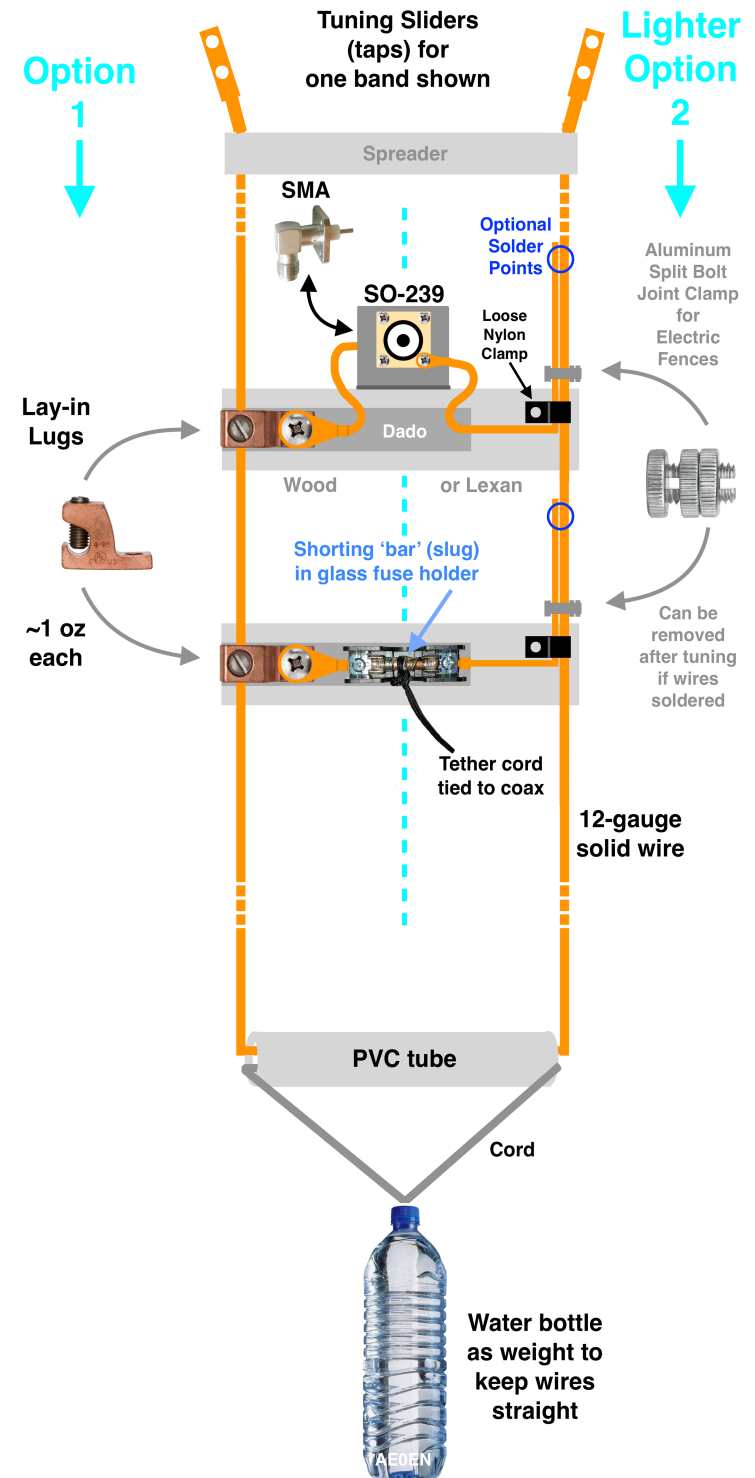
If a full **6-band, 6m-20m multi-band caged Hen-Delta** is desired (and recall that 6mX3 is ‘free’), the total weight of the tuning stub should be under 4 lbs (1.8 kg). A small 250W 1:1 current balun might add 1/4 pound (~100g), and the coax cable itself would add a bit more. I suggest mounting the small current balun on the coax cable and just let it hang free with the coax.

The 6-wire caged ‘downwires’ (using just 3 caging rings on each side) could be reduced from their present 12-gauge to 18-gauge stranded wires (six 18-gauge wires = one 10-gauge wire), or even 20-gauge stranded wires (six 20-gauge wires = one 12-gauge wire) per the link on page 44. The heavy top copper pipe replaced with a lightweight spreader (wood, PVC, fiberglass, or lacquered bam-

boo from a fishing pole) and a single 12-gauge wire. I estimate the total weight of the 15m ‘sail’ could be under 3 lbs (1.4 kg).

**This would bring the total weight of a portable 6-BAND caged Hen-Delta to ~6 lbs (~2.7 kg),** which should be deployable on a commonly available fiberglass pole or two (see page 73 for a 2-pole concept) to a reasonable DXing height of 33’-40’ (10m-12m). Higher is better for DX, of course.

A partially filled water bottle (or other convenient weight or bungee cord) at the bottom of the tuning stub would help keep the upper antenna ‘sail’ and the tuning stub under light tension to maintain the correct shape after having been rolled up for



transport. Some of the shape-maintaining PVC tubes and spreaders may need to be epoxied into place.

The illustration above is just a starting point, so feel free to create and test your own lightweight designs!

## LibreWriter 7.3.7.2 Opinion:

2025-0309: Caveat: This version 7.3.7.2 is not the latest, but is *relatively* recent and the latest this old iMac can use. Newer revisions may have already addressed the difficulties mentioned below...

Having exhausted the potential of Mac *Pages* early in the writing of this document, I had to choose between a very old QuarkXPress 2.0 running on a c2000 PowerMac under ‘prehistoric’ OS9, or look for new writing tools. LibreWriter (‘LW’) came to my attention. LibreWriter, an element of the *LibreOffice* suite of applications, is a **free**, open-source application of truly massive proportions – I am in awe at the mass of code that has been developed for it! So I elected to port my early work in *Pages* via *Word* to *LibreWriter*. I *love* what LibreWriter *is*... but I am disappointed in what it *is not*.

LibreWriter has an *Achilles's heel* so discouraging as to likely exclude it from future project consideration. I question if I would ever use it again... unless new knowledge of workarounds come to light, or have already been addressed and I simply don’t know of them.

This *Achilles's heel* appears to be intrinsic to the foundational paradigm of how images are managed. That paradigm is that images should flow with the text as new text is inserted in or removed from any page. For small images of dimensions less than a column wide and a few inches (or cm) tall, this probably works well. But this document requires many dozens of mostly-*large* images (an average of one image per page) which often don’t automatically relocate well relative to that text which discusses and explains them. In fact, the document layout quickly becomes *uncontrollable* in that an innocent edit on an upstream page can ripple down through the entire document with catastrophic damage to its prior neat and orderly appearance. I term this ‘*unintended reflow consequences*’, and it is quite reversible *if* you can find its origin point in the document. This may sound minor at first, but as you approach a publishable state with over 20 pages (this one is over 110 pages) you find you must carefully review the *entire document*, top to bottom, after any edit of more than one line, to ensure that something hasn’t moved detrimentally while you weren’t watching! But worse is in store...

To me, a more natural paradigm is that of QuarkXPress (QXP), in which images are anchored to a page (by default, not necessity) along with the text that applies to them. A page is isolated from adjacent pages unless specifically ‘linked’ to them, which is easy to do. On the other hand, LW pages are *always* linked to one another. In QXP, if you need to insert a page after page ‘n’, you

simply do so and all downstream pages – *and images* – are incremented by +1 page. For clarity I term this action ‘insert *blank* page’. LW does **not** offer this so far as I know. LW has an ‘insert page break’ which will move all *text* downstream by +1 page, but if you have anchored some images *to a page* – to prevent chaotic mis-positioning – ***those do not move!*** As a result all text and images anchored to *characters* or *paragraphs* flows around (or hide behind or on top of) those images anchored to the page. *Chaos then reins supreme!* Worse still, sometimes when *saving* a document LW will ever so slightly move an image with the consequence that when next *opened* it ‘hops’ to the next page, and reflow chaos runs wild! This is bewildering the first few times and *infuriating* by the tenth! *The document is perfect when you save it and a mess when you next open it!*\* I have begun saving every edited version with a new suffix (‘aaa’-‘zzz’) and also often as PDF format as *it* provides a clean version to refer to if I need to repair an incomprehensible reflow mess. I have lost ***hours*** doing this! After the last such LW stumble I went through this entire document and anchored ***every single image*** to its page! So far, so good... but I am *wary!*

LW has a concept called ‘sections’ similar to what I would term ‘chapters’ which might address this *Achilles's heel*, but it is not obvious that you should make every page its own section (chapter) so that you can later insert a blank section (page) where you need it. Neither is there a ‘convert page(s) to section(s)’ feature *that I am aware of* – LW is *enormously* intricate, complicated, and sometimes nonintuitive due to its broad, deep feature set...

...I am sure the kind reader will understand that I have other things to do with my life than to earn a PhD in LibreWriter – I need to get ***work done!*** Thus I have embraced the simple expedient of adding new topics via ***appendices*** with brief references to those appendices in the main body of the document where appropriate, and in the table of contents, of course. This is the best that I can do with the time available, and I appreciate the reader’s kind tolerance of related information possibly being in two places. At least it is *all here!*

My final advice to the LW world regarding ‘paradigm purity’ is simply this: ‘software should adapt to the needs of people, not the other way around.’ If the LibreOffice development association should ever add ‘insert blank page before/after current page’, I will enthusiastically endorse LibreWriter at that time.

\*Example March 9, 2025: When opening this document *on four occasions* today I discovered that LW had mysteriously lost track of the location of a ‘page

break' at the same place each time, moving it to the next page, thus shifting text by +1 page on all downstream pages. Fortunately, this fault was easy to find and repair on each occasion. I tried substituting a 'column break' but that didn't work either. Sometimes with LW (at least this version on this old iMac) 'what you see' is not quite 'what gets saved'...

...April 9, 2025: This problem has mysteriously ceased.

### **A Priority Message from AEØEN:**

**‘SK’ on horizon.**

**The following few pages are a short introduction to a 20-year log which I kept to ‘perpetuate the evidence’. Amateurs are welcome to read this, but it is intended primarily as a brief synopsis for university neurological researchers in all countries with ‘first world’ brain research facilities – especially Canada and Europe.**

**Amateurs are requested to phone or email this paper’s Archive dot org *link*, or mail a copy of the entire PDF, by flash drive or optical disk, to the universities of your choosing, making reference to this message appended at the end of the paper.**

**Thank you,**

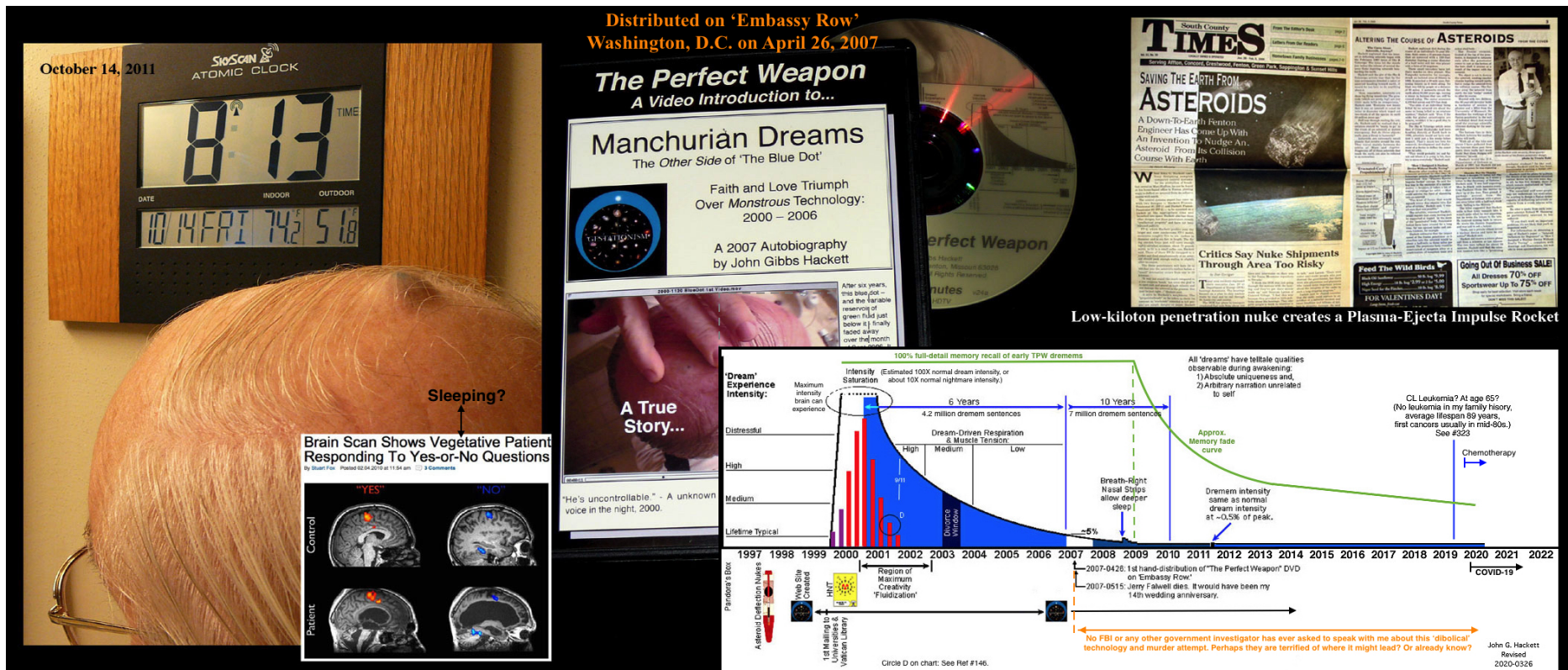
**AEØEN**

## PRIORITY MESSAGE FROM JOHN G. HACKETT, AEØEN:

2025-0905: 'SK' on horizon due to induced leukemia. I would like to request the assistance of the neurological research universities of: Canada, The Netherlands, France, Germany, and others to perform, supervise, and witness post-mortem brain imaging, dissection, neurological chemical analyses, etc., to determine the cause and nature of the **technology** employed to induce these horrific and unnatural symptoms, which might be reasonably characterized as 25 years of 'dreaming at the gates of hell'. I was NOT a volunteer experimental subject – this was essentially attempted murder via induced suicide. They failed, but leukemia was the result. The technology is so potent that I estimate the odds of suicide in the general population at 50%. The odds of some form of institutionalization is also 50%. The odds of surviving with an 'intact' persona (or soul) is roughly 1 in 1000.

The following illustrations are just a FEW EXCERPTS from my web site, **Gestationism dot com**, originally created in October 1998 to organize and

communicate my thoughts on a cosmological theology. After the **July 2000** attack in the middle of the night, I began to use this web site to 'perpetuate the evidence' as I did not know if I would survive, be allowed to survive, or to what *degree* I might survive. However, at that time I had two young sons and believed it prudent to be very 'oblique' about reporting these symptoms or claiming to have been assaulted, since our society is 'not intelligent' in dealing with 3- or 4-sigma events. By April 26, 2007 I felt it was safe to offer briefing material to 'the world' (precluded hypothetical U.S. suppression) and *hand-delivered* DVD video briefings named '*Manchurian Dreams*' (see below) to many embassies along 'embassy row' in Washington, D.C. The title name is a nod to the movie '*The Manchurian Candidate*'. I gave each embassy multiple copies for their intelligence agencies and to distribute at the pleasure of their ambassador. I also mailed copies, many from D.C., to the FBI, the CIA, dozens of congressmen, captains of industry, the media, various organizations, the ACLU, and everyone who might possibly wish an awareness of this weapon technology, and take appropriate action...



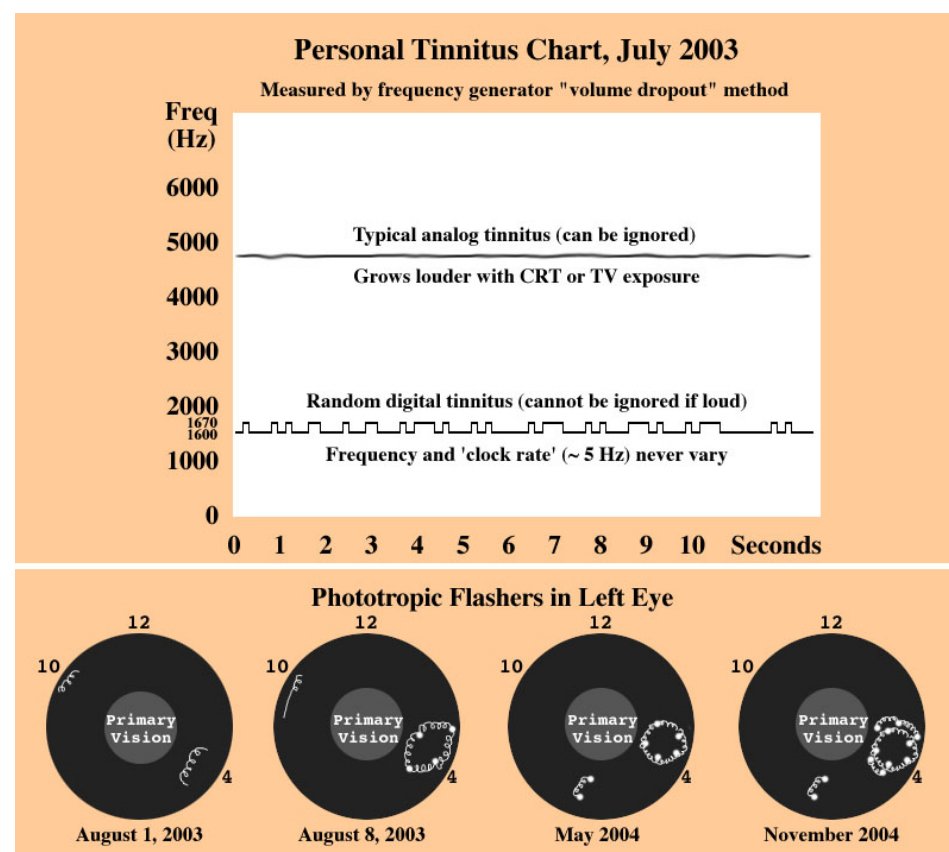
*This illustration may be zoomed in on to read detail.*

To my utter astonishment there was no response of any kind. Ever. A reasonable man would assume that the government – tipped off about a new and horrific anti-personnel technological threat – would ‘beat a path to their door’ and ‘turn over every rock’ to discover the nature and source of the threat. Yet... silence. This was ominous in several possible ways: Had our government devolved to being ‘dumb as cow tracks’? Or was this *U.S. classified technology* used (or tested) on a *U.S. Citizen on U.S. soil*? I lack the legal expertise of TV constitutional scholars, but I believe the latter qualifies as **treason!** Especially when said same technology is consequently reported to the world and lost forever. (‘What a shame.’) It also makes you wonder if the *Constitution* and *Bill of Rights* **mean anything** anymore, or are they just pretty pictures projected on monuments to keep the public docile? ‘*We The People*’ have **all** of our rights... as long as that isn’t too inconvenient for the government. And our FBI will investigate all crimes... so long as they don’t have to step on the toes of the rich and powerful, or upset politicians and their voting blocks.

The timeline chart above shows the sequence of events and the slow decline in dream intensity over two decades. It was impossible to *work* for more than a dozen years given this sleep-torment and sleep-deprivation. I could not even begin to *forget* any of the *hyper-intense* dreams (see ‘Saturation’ period on timeline chart above) until c2009.

The *digital* tinnitus illustrated at right, analyzed with a simple audio generator, would have been unsurvivable if it had continued at its original intensity beyond a week or so – I was sleeping for just an hour per night, plus a few short naps during the day. You can easily simulate this sound if you wish. Thankfully it subsided rapidly over weeks 2-6, and while still faintly present for 12-18 months, I was able to ignore it and get 5-6 hours of sleep routinely, plus naps.

For many years I believed the ‘phototropic flashers’ shown at right were in my eyes, but I discover just a few years ago that they are actually common to both eyes simultaneously. In other words, they are in my visual cortex. That makes sense in a way, given the dremems. Beyond their disconcerting novelty they are not troublesome.



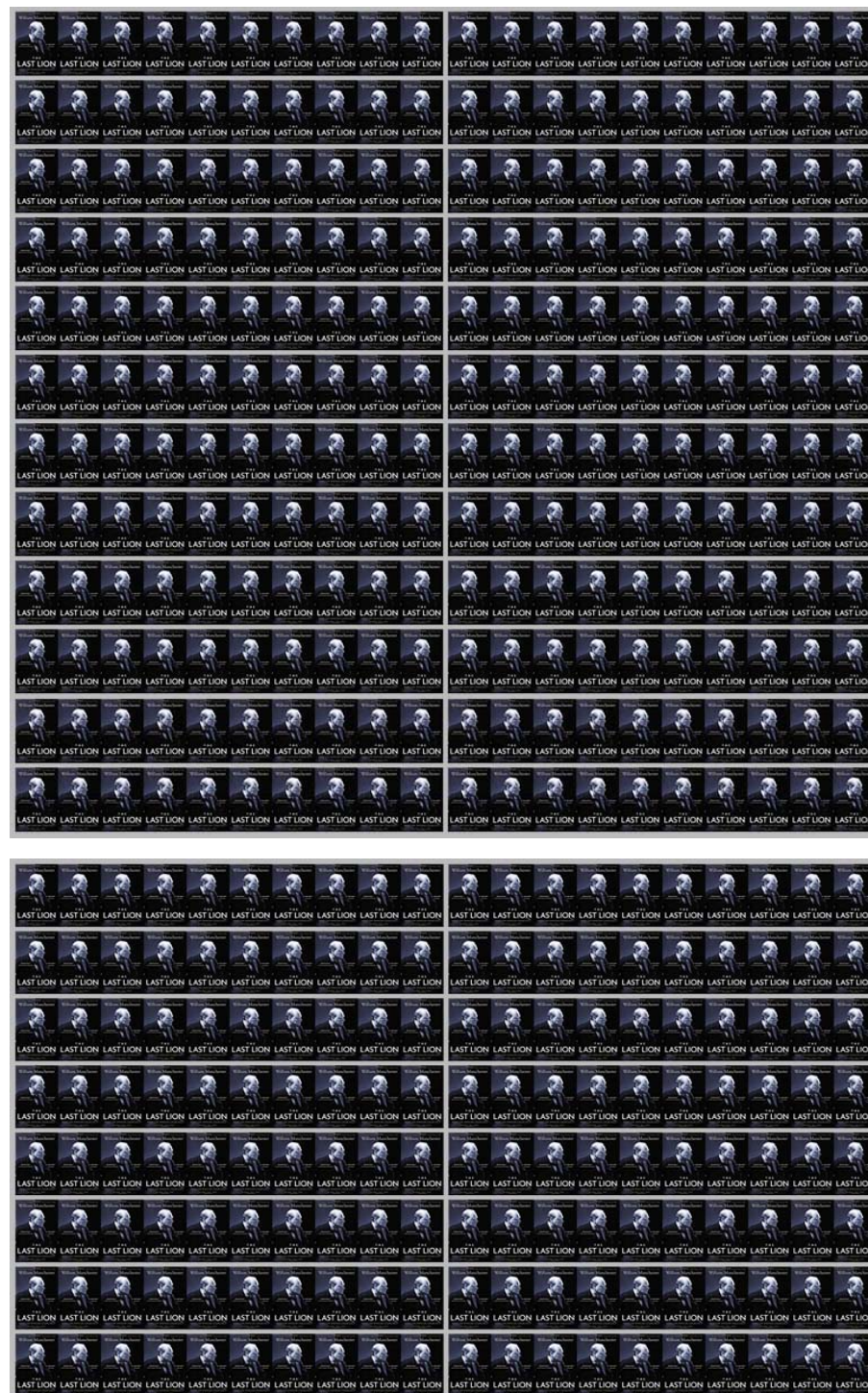
At right are **four hundred, 1000-page book** thumbnails illustrating the *same word count* as 25 years of ‘forced’ non-native dreaming – about one million dream sentences (of 5-7 words each) *per year*. It was useful to coin the term ‘dremem’ as a portmanteau of ‘dream’ and ‘memory’, as all dream content was non-native to my life, high resolution, and seems likely (as a guess) to have been injected ‘engram fragments’ from dozens of ‘donors’ with some kind of ‘neuro-processing accelerant’. This 25-year quantity of dremems is comparable to about 10% of my waking life memories. Unlike the 400 books shown here, the dremem sentences **never repeat** and are completely non sequitur to one another. Curiously, while the endless streams of dremem audio ‘directed and controlled’ visual dream content, they had *absolutely no relationship* to it. Neither did the dremem sentences always make sense linguistically or logically, but the dreaming mind accepts them uncritically. Corresponding visual imagery would be completely unrelated to the audio and to my life experiences – such as walking into ‘my home’ – but a home that I had never seen in real life. I have experienced more than 100 familiar ‘home’ memory fragments and I conclude that ‘home’ is a very important memory engram). Visual scene ‘cuts’ occurred every few sentences, and a typical visual scene was consistently 7-8 seconds in length. I suspect that is significant but I’m not certain in what way.

Over the months and years I accumulated this statistical universe of knowledge about dremems during the minutes of gradual awakenings when I was semi-conscious, or when I was suddenly awakened mid-dremem by a loud noise, and found that I could recall ~30 seconds of prior content, which I would write down.

This monstrous experience was *deliberately* inflicted upon me. Don’t ask me **how** I survived, but it was in part to be able to provide a detailed overview of this anti-personnel weapon technology to ‘the authorities’. Try to imagine my utter astonishment when in April 2007 I told ‘the world’ ... and **no one** was sufficiently interested to even speak to me. No investigator at any level of government – no person anywhere – **ever** suggested a debriefing. Nor so much as a casual chat. That is still true as I write this...

Long pause.

So... *what is this?* A quiet ‘off-book’ government assassination technology and the FBI just ‘knows’ to look the other way? Does the CIA select random citizens on U.S. soil to test their new experimental technologies on? Are various mass religion hierarchies allowed to occasionally murder anyone contemplating a new theology ... because they represent a huge voting block? What was it that



Thomas Jefferson wrote regarding mass religions?... **"I have sworn upon the alter of God, eternal hostility against every form of tyranny over the mind of man."** I imagine Jefferson is spinning in his grave *now*.

But perhaps this technology is something with more local roots in St. Louis, Missouri? Is there any reason why states, corporations, and religious institutions can't have their own 'classified' technologies derived from their university contacts, internal corporate research, or word-of-mouth serendipity? To better control their own competitive edge and ensure their future profitability? Why not? Who is going to stop them?

I call this weapon 'TPW' for 'The Perfect Weapon' because *even its victims* don't want to claim its use, and how *perfect* is that!

It is critically important to understand that the *use* of TPW constitutes a WMD **catalyst**. If that isn't instantly clear, ponder the results of its being used on major geopolitical and military figures. I promise you this: the afflicted persons will want to **strike back** at those they *believe* inflicted this horror upon them – whether the perceived aggressor is accurately chosen or not. If your nation doesn't understand and know how to detect TPW, *it* can control *your leaders*!

There is still time for a debriefing, but I suggest that interested parties not dither. I am reminded of this...

*On the plains of hesitation  
bleach the bones of countless millions  
who, at the dawn of victory,  
sat down to rest,  
and resting, died.*

-Unknown

The form of any debriefing is 'to be determined.' I communicate most precisely by written word, but I will try to be accommodating – note that my stamina is marginal.

You should not assume that the web site Gestationism dot com will always be available, so please download webarchive backup copies of all four pages and save them on optical media.

At right is proof that my briefing DVD was mailed to, then returned by, the FBI.

You can zoom in on this image to read the detail:



U.S. Department of Justice  
Federal Bureau of Investigation  
Washington, D. C. 20535-0001  
June 26, 2007

Dear Correspondent:

Because of the large volume of mail received by the FBI, our resources will not permit us to individually answer each communication we receive. However, we have personally reviewed your communication and have determined the following:

- (1) ☒ No violation within the investigative jurisdiction of the FBI was identified; therefore, we are unable to assist you with your complaint/inquiry.
- (2) ☐ Your concerns should be directed to your local or state law enforcement authorities.
- (3) ☐ You may wish to discuss your concerns with private legal counsel of your choice, a legal aid society, or a local bar association.
- (4) ☐ The FBI does not have statutory authority to provide you personal protection. Your concerns should be directed to your local law enforcement authorities.
- (5) ☐ No preprinted material is available concerning your topic. You may wish to check the reference section of your local library.
- (6) ☐ Your concern may be of interest to \_\_\_\_\_
- (7) ☐ We are unable to provide any information on the topic of your request inasmuch as FBI and Department of Justice policy prohibits comment on ongoing investigations.
- (8) ☐ Your communication has been forwarded to the FBI field division listed below. Please contact that division directly if you have any additional information. \_\_\_\_\_
- (9) ☐ Your communication has been forwarded to \_\_\_\_\_. Please contact that agency directly if you have any additional information.
- (10) ☒ Your material is being returned, as it may be of further use to you.
- (11) ☐ The information you are requesting can be found on our Web site at [www.fbi.gov](http://www.fbi.gov).
- (12) ☐ Please note the following: \_\_\_\_\_

Executive Secretariat Office  
Records Management Division

#### Postmortem analysis suggestions:

- 1) Be aware that the implant may have a retrieval tether(-antenna?) along the implant path and thus might be easily removed in minutes, leaving only a threadlike wound channel behind.
- 2) A high-resolution MRI should be done **LAST**, in case there are magnetic properties to the implanted device or micro- or nano-devices. There is an MRI machine in Baltimore that is capable of 0.1mm resolution on deceased tissue. Other facilities may have similar or better resolutions.
- 3) A high-resolution Xray should be done first.
- 4) A high resolution CAT-scan should be done second.
- 5) Synchrotron Xray or PET scans should be considered.
- 6) DNA analysis of brain material near the site of the implant to see if the DNA of other persons can be detected.
- 7) Look for tiny specks of radioactive foreign matter, especially polonium.
- 8) Analyze brain neurotransmitter chemistry to see if there is a distinct 'unnatural' imbalance in the affected volume vs more distant volumes.
- 9) Slides of tissue should be examined for traces of nano-devices and insertion-path damage.
- 10) To prevent my 25 years of dream (dremem) experiences from being transferred into, and thus inflicted upon, another human mind and soul, all brain tissue should be destroyed (burned to ash) upon final completion of the investigation. There is no urgency as to the duration of the research, but I would think that a few months would suffice.
- 11) Please publish all findings. Even if negative, this will narrow the scope of causation for future victims.

#### Contact information:

Because of the incessant plague of spam communications most forms of electronic communication are blocked or silenced, but you may try email at the address: johnhackett at apcconsultants dot com (my former business email). Begin the subject line with "TO AE0EN:". I am uncertain if the government interferes with my USPS mail, but you may try that also:

John G. Hackett  
1021 Villa Gran Way  
Fenton, MO 63026 USA

Be assured that I will *always* reply to serious, non-spam inquiries, either in-kind or as you suggest. If you receive no reply, then I didn't receive your message.

You may wish to occasionally check this PDF paper for updates.